NASA SPACE SCIENCE: EDUCATION/PUBLIC OUTREACH

Summative Evaluation Report
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EXECUTIVE SUMMARY

THE PROGRAM

This evaluation report examines the implementation of NASA's Space Science (SS) Education and Public Outreach (E/PO) Effort, which was developed by the Office of Space Science (OSS) in 1994–95 to make "education at all levels and the enhancement of public understanding integral parts of space science research activities."[1] The E/PO Effort aspired to link a number of existing and new NASA organizations across the country, allowing them to work in concert to support NASA's educational goals.

To this end, the NASA SS E/PO Effort developed the Support Network (SN), a network of institutions across the nation that were charged with supporting the goals of E/PO Effort, and of NASA's Office of Education. The intent was to build a bridge between the NASA Space Science and the public, particularly the formal and informal educational communities.

The SN comprised two types of institutions: Educational Forums and Broker/Facilitators (B/Fs). The Forums were charged with integrating data from diverse missions into coherent strands with content that could be mined for educational resources. The B/Fs were charged with reaching out to scientists and educators in their geographical regions, supporting collaborations, strengthening existing networks, and fostering partnerships.

Several administrative changes over the past five years have impacted the structure and function of the E/PO Effort. In 2004, a new Office of Education was created. Later that year, the Office of Space Science became part of the new Science Mission Directorate. Leadership of NASA, of the Office of Education, of the Space Science Enterprise, of the Science Mission Directorate, and of NASA SS E/PO has changed multiple times since 2001. Despite this, the Forums and B/Fs continued their work. Funding for the Forums and B/Fs will end in 2007. There are plans to replace the Forums and B/Fs with other institutions that will perform similar, but not identical, functions.

THE EVALUATION

In 1998, NASA's OSS contracted with the Program Evaluation and Research Group (PERG) at Lesley University to conduct an external evaluation of the NASA SS E/PO

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[1] *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs,* 1995, p.1

Effort. The evaluation was conducted in multiple phases, examining infrastructure, implementation, and impact. PERG has shared its findings in writing, in formal presentations, in informal conversation, and via email. NASA has responded to the evaluation with the aim of better meeting the needs of its constituents. PERG's prior reports are available online at http://science.hq.nasa.gov/research/epo.htm. This report references findings from earlier reports, as well as data collected specifically for this manuscript, to create a comprehensive picture of the NASA SS E/PO Effort over the years it has been in existence.

THE FINDINGS

Data suggest that the NASA SS E/PO Effort was successful in expanding the reach and impact of NASA E/PO resources. Members of the SN suggest that much of this success is the result of increased communication with, and respect for the opinions of, end users, that is the educators, learners, and leaders that the resources are meant to support. NASA SS E/PO developers report that their involvement with the E/PO Effort helped them better understand both the needs of their audiences and the current research about the best strategies to meet those needs. The types of SS E/PO resources that NASA supported and developed evolved significantly over the tenure of the E/PO Effort, in part because the system was highly responsive to the needs of its stakeholders and audiences:

- More inquiry-based, hands-on resources have been developed, reflecting current research on pedagogy; these resources fit realistically within the context of formal education, reflecting the constraints that classroom teachers face in terms of time, finances, and technology.
- Resources for classroom teachers are aligned with national and many state standards; in addition, the Space Science Education Resource Directory (SSERD, an online directory of NASA SS E/PO resources) allows educators to search for resources designed for specific grades and meeting specific standards.
- Resources for museums and science centers are more flexible and better able to meet the needs of institutions of various sizes, with various budgets, and at various levels of technological preparedness.
- Professional development opportunities have been expanded and now include a variety of longer-term programs that include collaboration between educators and scientists, allowing both parties to better understand the needs and constraints of the other.

Over its relatively short tenure, the NASA SS E/PO Effort has produced exemplary, award-winning materials for classrooms, museums, teacher training, and the general public. These materials reach learners of all ages and levels of preparedness, in all 50 states. Data indicate that learners find NASA resources to be engaging and inspiring, and

that the resources are effective in increasing understanding of scientific concepts and processes.

The Effort also worked to develop strategies to make space science more appealing to members of underserved populations, increasing the pool of candidates for the next generation of space scientists. Space scientists have traditionally been white men, with relatively few women, people of color, or differently-abled individuals pursuing careers or higher degrees in space science-related areas. The E/PO Effort has employed a variety of methods to make space science accessible to more people:

- The NASA SS E/PO Effort provided support for the MUI and MUCERPI, two grant programs which funded minority colleges and universities; one-third of the institutions funded by these programs included outreach to formal and informal K–12 education in their own communities.
- The NASA SS E/PO Effort forged relationships with a number of minority professional science organizations, leading to several fruitful collaborations between minority and mainstream scientists.
- The SN has developed and hosted workshops to help scientists, science educators, and E/PO professionals better meet the needs of differently-abled and perceptually-challenged learners.
- The NASA SS E/PO Effort hosted the Workshop to Foster Broader Participation in NASA Space Science to seed personal contacts among a more diverse community than had traditionally been active in NASA Space Science missions, with the aim of increasing partnerships and collaborations among mainstream and minority researchers.

Those who have worked within or in close collaboration with the NASA SS E/PO Effort report that the experience has been a positive one for them, that they believe they have a better understanding of what constitutes quality space science educational material, and that their involvement with the NASA SS E/PO Effort will continue to positively influence their ongoing work in E/PO.

At the time that the NASA SS E/PO Effort was developed, NASA's Office of Space Science lacked a unifying structure for developing educational resources. Lack of communication among education developers, scientists, and end users led to a complex array of resources with many gaps and redundancies, and few criteria for ensuring consistent quality. The earliest days of the Effort mirrored this complexity: The initial goals of the Effort were multi-faceted, roles were not clearly defined, and communication was haphazard. Over time, the Effort developed a more streamlined set of roles, goals, and communication systems:

- Goals and objectives were simplified and integrated, and measurable benchmarks were developed.
- Input from evaluation reports, the Task Force, and the SN were used to formulate more specific actions and objectives for the components of the system, especially

the Broker/Facilitators—a new role that required some time and effort to define clearly.

- The system developed an array of tools to communicate across members (Education Council meetings, Broker and Forum retreats), with scientists and education developers (Forum and theme retreats, newsletters, conferences), and end users (web pages utilizing user input, presence at conferences, the SSERD, audience involvement in resource development and review).
- Both the system as a whole, and individual components within the system, developed more extensive procedures for product review and quality control, as well as ways to share information about quality with end users.

The Effort faced the challenge of overcoming the divide between research science and education. Cultural differences—especially differences in communication style—led to clashes when the SN first brought together scientists and educators. Over time, the SN orchestrated a variety of situations in which scientists and educators could come together to share their expertise as they worked together to create resources and to develop themselves professionally and personally. Many members of the SN have become experts in meeting the needs of various end user populations (e.g., scientists, formal educators, learners with sensory deficits), and continue to share their expertise with their colleagues.

Early efforts to integrate scientists into education were met with resistance by those who viewed work in education as a distraction from research and publication. The Effort employed a number of strategies to make educational work easier, more appealing, and more effective for scientists.

- The administration mandated that 1–2% of every mission budget be dedicated to E/PO, and encouraged Supporting Research and Technology programs to develop E/PO components, as well.
- The SN supported a variety of workshops (from two-hour workshops at science conferences to more intensive multi-day training opportunities) to provide scientists with the skills needed to contribute to successful educational resources.
- The SN brokered partnerships between scientists and education specialists who could maximize the value of the scientists' knowledge and expertise; this allowed scientists who may have dismissed E/PO work as too time-intensive to share their knowledge with others who could use it to develop effective E/PO resources.
- The NASA SS E/PO Effort recognized the achievements of scientists in education, and supported other forms of recognition, such as NASA awards, and the development of *The Astronomy Education Review*, the first peer-reviewed journal dedicated to space science education.

Data indicate that these strategies were successful in providing scientists with the resources and motivation to contribute to educational resources. Scientists report that the positive experiences they had working with the NASA SS E/PO Effort, along with their own understanding of the intrinsic value of education, have inspired them to find ways to incorporate educational development into their careers.

INTRODUCTION

From its inception in 1958, the National Aeronautics and Space Administration (NASA) has sustained an agency-wide commitment to education. During the period December 1993–February 1995, the NASA Office of Space Science (OSS) developed *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs* (1995, referred to as the Strategic Plan). This publication articulated the goals of developing a variety of Education/Public Outreach (E/PO) resources and integrating them with existing efforts to create a coherent vision for education. *Implementing the Office of Space Science Education/Public Outreach Strategy* (developed May 1995–September 1996, referred to as the Implementation Plan) specifically addressed the methods by which the goals articulated in the Strategic Plan were to be realized. The goals and outcomes have evolved over time, but throughout the tenure of the NASA SS E/PO Effort, the personnel associated with the Effort remained flexible enough to meet the changing goals while continuing to support the mission of the Strategic Plan: making "education at all levels and the enhancement of public understanding of science integral parts of space science research activities."[2]

PROJECT DESCRIPTION

In 1996, the NASA Office of Space Science (OSS) Education and Science staff developed an E/PO strategy and Implementation Plan to accomplish the agency mission by integrating a variety of existing individual, isolated efforts and newly planned activities into a coherent vision. Virtually all of these efforts were funded through OSS flight missions,[3] through grants for Guest Observers and Supporting Research and Technology[4], and through the activities of the Support Network (SN), described below.[5]

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[2] *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs,* 1995, p.1.

[3] Missions are large-scale, long-term research projects. The funding process for missions utilizes Announcements of Opportunity (AOs). The OSS E/PO Effort mandated that all new missions allocate 1–2% of their budget for education and public outreach. Older missions, such as Voyager, were exempt from this mandate, although many did support some type of E/PO development.

[4] Grants for Guest Observers and Supporting Research and Technology are smaller grants, covering relatively small, short-term research projects that provide basic research supporting the flight missions. The funding process utilizes NASA Research Announcements (NRAs), and grants submitted in response to NRAs are not required to include funds for E/PO. While educational components are not mandated for Supporting Research, scientists working on Supporting Research are encouraged to develop E/PO resources in conjunction with the scientific content of the grants.

OSS guidelines required that scientific staff be involved with the development of E/PO related to their missions and research. Scientific staff were often supported by personnel dedicated specifically to development of E/PO resources.

DEVELOPMENT OF THE "ECOSYSTEM" AND SUPPORT NETWORK

The strategy developed to support the OSS E/PO program envisioned creation of a space science E/PO "Ecosystem," so called because it was meant to be a self-sustaining system, which would evolve to meet the needs of the community. The term "Ecosystem" was later dropped due to confusion related to its more familiar terrestrial connotations, and the program was simply referred to as the OSS E/PO Effort.

The OSS E/PO Effort resulted from a collaboration of scientists and educators from within:

- NASA's Office of Space Science
- The NASA Education Division
- The OSS education community
- Science research communities
- University and college education communities
- Minority university and college communities
- The formal and informal education communities[6]
- District and statewide education reform communities

The OSS E/PO Effort was directed towards linking a number of existing and newly funded organizations and staff across the country. The OSS E/PO Implementation Approach was defined by the following vision statement:

> The Office of Space Science will use its knowledge and discoveries about the Sun, the solar system, the galaxy, and the universe to develop E/PO opportunities and activities that enhance science, mathematics and technology education and the scientific and technological literacy of all Americans. [7]

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[5] There were a few smaller grants programs, such as IDEAS, that provide E/PO funding that is not tied to specific NASA missions or Supporting Research. These represent a very small proportion of the OSS E/PO budget.

[6] For the purposes of this report, formal and informal education are defined as the following: formal education is what happens in schools as part of a progressive (not in the political sense, but in the developmental sense) curriculum and is usually assessed; informal education is what happens in "free-choice" environments, such as museums, clubs, etc. (George Hein, Educators Network Listserv).

[7] *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs,* 1995, p.2.

The 1995 OSS document, *Partners in Education*, included the four OSS E/PO goals as they were articulated at that time.[8] Those goals stated that the OSS would:

- Use space science missions and research programs and the talents and resources of its research and development communities to make significant and measurable contributions to meeting national goals for the reform of science, mathematics and technology education, particularly at the K–13 level, and the general elevation of scientific and technological literacy throughout the country;
- Continue to support the education and training of graduate students and postdoctoral fellows in space science in order to create the talented scientific workforce needed for the 21st century;
- Promote the involvement of women, underrepresented minorities, and students with disabilities in its educational programs and their participation in space science research and development activities; and
- Facilitate and cultivate strong and lasting partnerships on local, regional and national scales between the space science research and development communities and the professional communities in science, mathematics, and technology education.

One of the features of the OSS E/PO Effort was the creation of a Support Network (SN) that could reach K–12 schools, universities and colleges; informal education organizations; and an array of media and public venues. The intent was to build a bridge between the Office of Space Science and the public, particularly the formal and informal educational communities.

The SN initially comprised four Forums and five Broker/Facilitators (B/Fs). The Forums corresponded to OSS's four research themes at the time the SN was developed (Solar System Exploration, Sun-Earth Connection, Structure and Evolution of the Universe, and Astronomical Search for Origins). As every OSS mission was aligned with one of these themes, the Forums created a network that included every OSS mission. The B/Fs were a new construction, geographically spread across the nation and conceived as working regionally with users of OSS's educational products and identifying needs that the OSS E/PO Implementation Approach could address.

The administrative head of the SS E/PO Effort was the Assistant Associate Administrator for Education and Outreach (AAA) in OSS. The AAA was "the OSS focal point for all issues concerning education and the public understanding of science." The AAA was responsible for overall policy development and implementation, budgeting and general oversight, and the evaluation of OSS education and outreach programs."[9] The AAA, the

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[8] *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs,* 1995, pp.3-4.

[9] This description is taken from the unpublished draft of the *Space Science Management Handbook* (p. 9–1).

Forums and B/Fs (the Support Network), together with staff from OSS education, NASA Education Division, and the Minority University Research and Education Division (MURED), formed the basis of the OSS Education Council—the group created by OSS to promote coordination of E/PO efforts and implement the OSS-wide plan.

The OSS Education Council met regularly to share information and experience, to develop the necessary infrastructure and resources to support the continuing activities of the OSS E/PO Effort, and to provide professional development opportunities for its members. These meetings served as benchmark events, creating the opportunity for all members to communicate and interact with each other, with the rest of OSS, and with NASA administration. The AAA used these meetings to support a number of purposes, such as oversight, review, and coordination of efforts with other organizations within and beyond NASA. A fuller description of the original OSS E/PO Effort and its components can be found in the first PERG evaluation report prepared for the system.[10]

As a consequence of SN activity, the OSS E/PO Effort increased in connectivity and integration. During the period covered by the evaluation, the SN and its components continued and expanded the work it had been involved with over the previous years, including outreach to the educational, scientific, and underserved communities; development and implementation of educational resources and systems; refinement of the SN infrastructure; and coordination of activities with NASA's Office of Education. Over time, the goals, roles, and terminology changed to better meet the needs of the system and its users.

In 2000, a new strategic plan was developed. The goals of the Effort as outlined in the 2000 OSS Strategic Plan were:[11]

- To share the excitement of space science discoveries with the public
- To enhance the quality of science, mathematics, and technology education, particularly at the pre-college level
- To help create our 21st century scientific and technical workforce

In 2001, the original B/F awards expired. Four of the original five B/Fs were refunded, and three new B/Fs were added, bringing the total number of B/Fs to seven.

Also in 2001, the Space Science Advisory Committee (SScAC) set up a task force to carry out an external review of the OSS E/PO Effort. The SScAC E/PO Task Force

[10] Cohen, S.B., Griffith, J, Gutbezahl, J, & Lynch, M. *The Office of Space Science Education/Public Outreach November 1998—December 1999 Evaluation Report*, 2000. Cambridge MA: PERG.

[11] *The Space Science Enterprise Strategic Plan, 2000*, p. 23.

review[12] found the Effort to be worthwhile and effective. The report included several substantive recommendations for improvement, such as to better integrate minorities into E/PO development, to clarify the Broker/Facilitator role, and to provide more extensive internal professional development (PD) for those involved in E/PO development. OSS administration implemented many of these recommendations. Partly as a function of the Task Force report and findings from PERG evaluations, the Education Council meeting agendas were modified to include a range of interactive activities and PD opportunities for its members. The agendas also included expanded opportunities to dialogue directly with members of the NASA Education community, as well as external groups such as minority professional organizations, formal and informal education organizations, and public outreach groups.

In late 2005, an external review panel assessed the SN. The panel reported that the NASA SS E/PO Effort and SN had made measurable progress and experienced documented successes; the panel also indicated that "this program could be considered as a model for the agency-wide educational effort."[13] The panel suggested several changes, including further clarification of goals and objectives, and improving communications both internally and externally.

ADMINISTRATIVE CHANGES

Prior to 2002, membership and leadership of both OSS and the E/PO Effort were fairly stable. Other than the changes in B/Fs when their awards expired in 2001, there were few changes in the SN, and the administration of OSS and its E/PO Effort remained in place. Since 2002, several administrative changes in NASA have affected the structure and function of the SS E/PO Effort.

In late 2001, a new NASA Administrator was appointed. The new Administrator made several systemic changes, including creating an Office of Education through the merger of the Education Division and Minority University Research and Education Division (MURED). In 2003, the Office of Education developed new NASA education goals, which superseded the OSS E/PO goals:

- Strengthen NASA and the nation's future workforce—NASA will identify and develop the critical skills and capabilities needed to ensure achievement of the Vision for Space Exploration. To help meet this demand, NASA will continue contributing to the development of the nation's science, technology, engineering and mathematics, or STEM, workforce of the future through a diverse portfolio of

[12] *Implementing the Office of Space Science Education/Public Outreach Strategy: A Critical Evaluation at the Six-Year Mark (2003)*

[13] *NASA Science Mission Directorate E/PO Support Network Review Panel Report (2005).* p. 1.

education initiatives that target America's students of all levels, especially those in traditionally underserved and underrepresented communities.

- Attract and retain students in STEM disciplines—To compete effectively for the minds, imaginations, and career ambitions of America's young people, NASA will focus on engaging and retaining students in STEM education programs to encourage their pursuit of educational disciplines critical to NASA's future engineering, scientific and technical missions.
- Engage Americans in NASA's mission—NASA will build strategic partnerships and linkages between STEM formal and informal education providers. Through hands-on, interactive, educational activities, NASA will engage students, educators, families, the general public and all agency stakeholders to increase Americans' science and technology literacy.

In 2004, NASA reorganized, merging the Office of Earth Science and Office of Space Science into the Science Mission Directorate (SMD). A new Assistant Administrator (AA) for SMD was appointed.

In 2005, a new NASA Administrator was appointed. The new Administrator appointed a new AA of the Office of Education and a new AA for SMD. In 2007, the AA for SMD was changed again. In all, since 2001, there have been 2 changes of NASA Administrator, 3 changes of AA for Space Science (either as OSS or SMD), 4 changes of leadership for NASA Education, and 4 changes of leadership for NASA SS E/PO (either as OSS or SMD).

The funding for the existing Forums and Broker/Facilitators will end in Fall 2007. There are plans to replace the Forums and B/Fs with other institutions that will perform similar, but not identical, functions.

EVALUATION

The NASA Office of Space Science contracted with the Program Evaluation and Research Group (PERG) of Lesley University in October 1998 to conduct an external evaluation to determine how effectively the NASA SS E/PO Effort was meeting the objectives laid out in the Implementation Plan. The PERG evaluation plan from 1998 to 2005 comprised four phases presented in separate reports. This report represents a summation of the work done in the first four phases, plus analysis of data collected specifically for this report to assess long-term impact.

- **Phase I**
  The first report documented and described the **infrastructure** of the NASA SS E/PO Effort, especially the SN. Data analyzed were collected primarily from members of the NASA SS E/PO community. Data were collected between November 1998 and October 1999, and the report was delivered in May 2000.

- **Phase II**
  The second report described and explained the total NASA SS E/PO Effort **implementation**, beyond the development of the SN infrastructure. Data for this report were gathered between January 2000 and May 2001, from both members of the NASA SS E/PO community and the communities it serves directly (educators,[14] scientists, and the rest of NASA). This report focused on the actions taken to meet the goals outlined in the Strategic and Implementation Plans, the successes of the program, and the challenges that it faced.
- **Phase III**
  The third report examined the **impact** of NASA SS E/PO activities on those audiences for whom the products and services are designed (e.g., teachers who participate in NASA SS teacher training programs, visitors to NASA SS museum exhibits, etc.). Data sources included the audiences or "end users," as well as those populations who were included in the first two reports. Phase III of the evaluation took place over a two-year period that began in October 2001.
- **Phase IV**
  The fourth report was a multi-faceted document addressing three main evaluation questions:
  - *How is the NASA SS E/PO Effort meeting the needs of underserved audiences?* The first two sections of the report focused on partnerships geared at supporting underserved populations. The first section examined several recipients of Minority University Education and Research Partnership Initiative (MUCERPI) grants. The second section focused on partnerships that developed during Chicago 2004: A Workshop to Foster Broader Participation in NASA Space Science Missions and Research Programs, a workshop with the goal of seeding personal contacts among a more diverse community than had traditionally been active in NASA Space Science missions.
  - *What types of resources are most likely to meet the needs of the NASA SS E/PO Effort's end users?* As part of the Phase III evaluation, various resource developers (scientists, E/PO specialists, etc.) and end users (educators, learners, members of the general public, etc.) identified attributes of space science educational resources that are important to them. Evaluators conducted a large-scale (n=420) survey of the various populations involved in creating, supporting, and using NASA space science E/PO resources.
  - *What are the effects of specific NASA SS E/PO Effort programs that have been in existence for an extended period of time?* The final sections of the report focused on two programs that had been existence for more than five years; featured interactions among researchers,

[14] In this report, we use the term "educator" to refer to any individual or organization that is responsible for disseminating information to a larger audience. This includes (but is not limited to) classroom teachers, museum staff, librarians, Girl Scout leaders, speakers presenting to the public, etc.

teachers, and students; and combined formal education with active current research.

In addition, during the course of the evaluation, PERG has evaluated several specific NASA Space Science E/PO resources including:

- Chicago 2004: A Workshop to Foster Broader Participation in NASA Space Science Missions and Research Programs, described above as part of the first question addressed by the Phase IV report
- Space Place, a program to make SS materials available to a range of audiences, described more fully on page 27
- The Research Opportunities in Space Science (ROSS) E/PO supplemental awards; researchers who receive ROSS grants for supporting research are encouraged, but not required, to submit proposals for accompanying E/PO projects
- The *Cosmic Questions* museum exhibit, an interactive exhibit to promote understanding of and reflection about the structure and evolution of the Universe, described more fully on page 27
- The NASA/Girl Scouts relationship, which aimed to raise women's and girls' awareness and comprehension of SS, described more fully on page 28

The PERG evaluation reports are online at http://science.hq.nasa.gov/research/epo.htm.

EVALUATION METHODS

Data Collection Activities

Throughout the evaluation, evaluators employed a suite of data collection methods including formal and informal interviews and surveys, using phone, email, online survey instruments, and face-to-face protocols; ongoing web site review; and document review which included the Strategic and Implementation Plans, the 2003 SScAC Task Force report, the 2005 NASA Review Panel Report, internal and external newsletters, the 2000–04 Annual Reports, and the Space Science Education Resource Directory (SSERD) among others. They engaged in numerous informal conversations with both end users and members of the NASA SS E/PO Effort throughout the evaluation period.

Evaluators attended a variety of events hosted by the SN and/or its component institutions including conferences, workshops, teacher trainings, the first NASA SS Education conference, and Chicago 2004: A Workshop to Foster Broader Participation in NASA Space Science Missions and Research Programs. Evaluators also observed classrooms, museums, events, and workshops that utilized NASA SS E/PO resources. At these events, evaluators observed activities and interactions, interviewed participants, and provided formative feedback, as appropriate. These observations provide first-hand

evaluative evidence supporting data gathered from resource developers and users, creating triangular support for interview-based findings.

Evaluators also attended a variety of scientific and educational conferences—such as the meetings of the American Geological Union (AGU) and the National Science Teachers' Association (NSTA)—which featured a strong NASA SS E/PO presence. At these conferences, evaluators observed NASA SS presentations and workshops, interviewed or surveyed attendees, and engaged participants in informal discussions on topics relevant to the evaluation.

In addition, evaluators conducted a variety of in-depth studies of selected education resources to study the Effort's effects in a more closely focused way. Resources selected for in-depth studies included long-term programs with significant success, partnerships, and conferences. In-depth studies included observations, interviews, surveys, and reviews of documents and artifacts. Site visits involved intense on-site data collection, which included observations and associated interviews and surveys, as appropriate.

Participant Audiences

Evaluators gathered data from a wide range of individuals whose comments, ideas, and concerns are reflected in the report. These people include:

- **Members of the Education Council**—including the SN, as well as NASA SS E/PO administration, and staff from NASA's Office of Education
- **NASA SS and NASA Education personnel**—including staff working on E/PO within missions, E/PO developers associated with NASA SS research projects, and others playing important roles in the creation of NASA SS E/PO
- **Scientists**—including mission scientists, research scientists, and discipline scientists; scientists interviewed include NASA civil servants, employees of organizations working with NASA, university professors, and others actively engaged in SS activities
- **Other E/PO partners**—including publicly- and privately-funded organizations and individuals who have worked with NASA SS personnel to create space science education resources, identified by NASA SS E/PO staff and the NASA SS E/PO Annual Reports
- **Space science education providers beyond NASA SS**—including publicly- and privately-funded organizations and individuals who have created space science education resources without input from NASA SS personnel (outside of identified partners)
- **Formal and informal education personnel**—including K–12 teachers, museum staff, librarians, and others engaged in the process of educating the public
- **Volunteers**—including current and former space scientists, as well as amateurs with knowledge of and interest in sharing space science information

- **Learners of all ages who participate in NASA events**—including students, museum visitors, Girl Scouts, space camp participants, and others who learn using NASA resources

In all, several thousand individuals contributed to the data collection in some form or other. Many individuals have been interviewed, observed, or surveyed multiple times, allowing evaluators to observe change over time.

Tables 1 through 5 below show the data collected in each of the first four phases of the evaluation. They do not include the myriad informal conversations with scientists, educators, and NASA personnel conducted at meetings, visits, and conferences, nor do they include participation in telecons, videoconferences, etc.

Table 1: Interviews

	Phase I	Phase II	Phase III	Phase IV
SN	Multiple discussions with all members	11	28	
NASA SS E/PO staff		27	5	107
NASA Office of Ed/HQ		17	3	3
Scientists		53	40	145
Formal educators		18	80	219
Informal educators		9	54	112
NASA SS E/PO partners		2		6
Non-NASA E/PO providers		6		
Higher ed. (incl. minority institutions)			27	
Community groups			10	1
Libraries			22	
Volunteers (e.g. Ambassadors)			41	
Chicago Workshop participants				98
General public				48
Students				
Other			11	

Table 2: Surveys

	Phase I	Phase II	Phase III	Phase IV
Scientists			15	
Formal educators			84	22
Informal educators				8
NASA SS E/PO Partners				53
Volunteers (e.g. Ambassadors)			64	
Chicago Workshop participants				206
General public				
Students				57

Table 3: Observations

	Phase I	Phase II	Phase III	Phase IV
SN	14	8	11	6
NASA SS E/PO staff		6		
Formal education programs		8	10	6
NASA SS E/PO-sponsored conferences			1	2

Note: Each observation provided opportunities for multiple interviews and informal conversations with participants and stakeholders.

Table 4: Focus Groups

	Phase IV
Formal educators	1
Community groups	1
Students	2

Table 5: Case Studies

	Phase IV
Minority-serving institutions	3
Formal education programs	2

Note: Case studies include observations, surveys, and interviews with multiple participants; in some cases they also include focus groups.

THIS REPORT

This is a summative report and includes references to data from earlier evaluation reports, as well as analysis of data collected specifically for this report. In addition to the history of the program (presented in the introduction), the report contains two main sections:

- **Impact** examines the impact that the NASA SS E/PO Effort has had on those who have been involved with it as participants, supporters, or end users.
- **Strategies for Growth** examines the challenges faced by the NASA SS E/PO Effort (identified by prior evaluation reports, the Task Force, the Review Panel, and members of the NASA SS E/PO Effort itself) and how these challenges were addressed.

To gain a broader perspective of the program and its evolution over time, evaluators recently interviewed one or two members from each of the four Educational Forums, and from each of the seven Broker/Facilitators. These interviews were intended to gather information about the history of the NASA SS E/PO Effort, its role within NASA and the space science community, changes over time, and impact on end users. Because the

questions in this interview were multi-faceted and complex, the protocol was emailed to respondents to allow them to look over the questions prior to the interview. The protocol is given in Appendix A.

Most of the data presented in this report are *qualitative*. Qualitative data allow for deep exploration of a variety of areas, including many that are uncovered during the data collection process. Analysis of qualitative data can uncover ideas, beliefs, attitudes, challenges, etc. that are present in the population of interest. Unlike quantitative analysis, qualitative analysis cannot be used to estimate the prevalence of any specific variable, because the data are not representative of the larger population beyond the participating sample.

Throughout the report, there are citations from the data. For each citation, the evaluation phase in which it was collected, and the role of the individual cited, are provided. These quotes are included to add context and richness to the discussions and to illustrate the perspectives of those engaged in the work. All data cited in the report have been selected to *represent the themes and trends* that emerged from the data and are characteristic of the *perspectives voiced by multiple respondents* and issues related to the program during the report period.

IMPACT

Data suggest that the NASA SS E/PO Effort was successful at expanding the reach and impact of NASA E/PO resources, reaching educators and learners across the nation, including many who had not been served by pre-existing SS E/PO resources.

> It's grown from three or four programs nationally, to hundreds of efforts, maybe even in the thousands. Nice thing about this program is it's distributed but integrated. (SN member, final phase)

Data indicate that members of the NASA SS E/PO Effort greatly increased their collaboration with audience groups and education experts. Consequently, many individuals within the Effort acquired a knowledge base about user needs and effective resource development. This knowledge base continues to hold potential as an extremely valuable resource to aid former members of the Effort in creating resources that have impact on users.

> I think I'm more thoughtful. I would instead of jumping right in and saying, "I have all these great ideas!" I'd ask about their needs, their goals, their expectations. Now I'd do more quizzing of what their needs are before letting them jump on what would look good. (SN member, final phase)

Data suggest that success was related to several important aspects of the NASA SS E/PO Effort:

- The amounts of money involved were quite large. Mission budgets generally range from tens to hundreds of millions of dollars. By mandate of NASA SS administration, E/PO accounted for 1–2% of the total budget—a significant amount of money.
- The availability of funding and E/PO professional development supported involvement with space science E/PO as a respectable career move for NASA scientists and engineers, allowing those with interest to focus their energy in that direction.

> My career wouldn't suffer by doing E/PO work now. You can show that it is a valid part of the program. In recruitment of new science faculty here, E/PO is now a major issue. It is seen here as invaluable and my colleagues also view it that way. (Scientist, Phase II)

- E/PO proposals resulted from collaboration between scientists and E/PO staff working together to develop a strong proposal. In some cases, members of the SN were enlisted to assist with the E/PO design.

> I should point out that the AO [Announcement of Opportunity] proposals generally come from consortia. The PI [Principal Investigator] for one of these missions is in charge of the whole thing . . . The second member is a national laboratory; [the third is] an industrial partner; a fourth member is one of these E/PO providers. (Program scientist, Phase II)

- While guidelines required that scientific mission staff remain involved with the E/PO component, most missions employed dedicated E/PO staff. The E/PO staff gathered information and transformed it into the planned products, events, and services destined for K–12 education, higher education, museums, and the public. The scientific and technical staff were responsible for assuring the accuracy of these resources and providing scientific expertise.

NASA AND THE SS COMMUNITY

ENGAGING SCIENTISTS

Engaging scientists in education and public outreach was one of the stated goals of the NASA SS E/PO Effort since its inception. Data indicate that scientist involvement in education increased steadily during the Effort.

> I've been impressed with how many people that were involved with scientific research are now involved in education. It's been really great to see so many highly trained scientists involved in education initiatives. It's been very powerful what they bring to the table. (SN member, final phase)

The NASA SS E/PO Effort worked to support scientists who wanted to participate in E/PO but had limited time. For example, one B/F created the Regional Opportunities for Scientists in Education (ROSIE), a table of E/PO opportunities for scientists who have varying levels of experience and time to devote to E/PO. B/Fs had databases of scientists in their region that they reached out to, providing them with encouragement and the information they needed to participate in E/PO activities at a level of involvement that was appropriate and comfortable for them.

The NASA SS E/PO Effort supported a series of four-day workshops for scientists wanting to learn more about developing E/PO. At the workshops, scientists had the opportunity to meet with teachers, visit schools, observe classes, and work with hands-on classroom materials. Scientists reported that the workshops increased their awareness of the complexity of E/PO and made explicit the different ways they themselves could become involved.

The NASA SS E/PO Effort involved scientists in the creation of effective resources working in conjunction with organizations such as TERC, Lawrence Hall of Science, and McRel. Such partnerships allowed scientists to utilize their content expertise while others, more familiar with current educational research, shaped the content into pedagogically sound resources.

> Collaboration between someone who's an expert in the subject and someone who's an expert at teaching, that's the best way to do it.
>
> (Resource developer, Phase III)

> I think, basically, understanding user needs more deeply has affected the type of resource we developed. In the past, we developed individual lesson plans on a NASA topic, or a Sun-Earth topic. Now we partner with a curriculum developer that has many years of experience, like the Lawrence Hall of Science, develop a comprehensive set of materials that fit better with the context of the classroom . . . The scope and sequence fits within the constraints of the classroom.
>
> (SN member, final phase)

Scientists reported that they benefited from personal interaction with teachers and students, which allowed them to experience directly what teachers and students need and want.

> I have a better sense of what does and doesn't work in the classroom because I have contact with teachers. (Scientist, Phase IV)

> It gives me an opportunity to talk to students regularly, which I really value. (Scientist, Phase IV)

Some scientists reported that once they had an opportunity to do E/PO work, they found it an enjoyable and satisfying experience. This inspired them to do further work in education.

> I think once you do it and see the results, it gets higher on your priority list. It's self-propagating. (Small E/PO grant recipient, Phase IV)

> This was the first time I took my E/PO work to a higher level. It allowed me to think beyond the volunteer work. How could I, and my connection to NASA, help a great organization? (Small E/PO grant recipient, Phase IV)

> It's rewarding to see people's reaction to astronomy. It's such an inspirational thing when you share: the discoveries, what a scientists does, the outcome of a mission, or process of a mission, launch a rocket, how you build satellites. All these questions that people have, when [they hear the] answers they get so excited and interested. It uplifts the human spirit and that comes through when you start sharing with people. (SN member, final phase)

As more scientists devoted time to education, the scientific community placed more value on involvement in education, further increasing participation. Scientists were able to recognize a variety of benefits from their involvement in education, including respect from peers and positive feedback from end users.

> Everyone's always been extremely positive. When I discuss it with scientists in the community, they've been supportive. People have sent me rocks and images to use. (Small E/PO grant recipient, Phase IV)

> It's gradually gaining higher profile. The response has grown; people are more supportive now. (Small E/PO grant recipient, Phase IV)

> Sometimes I think I get more out of it than [the teachers and students I work with] get out of me. Of course, I haven't heard any complaints, so maybe they feel the same way. (Scientist, Phase IV)

Scientists reported that their involvement with E/PO provided networking opportunities with others sharing their interests.

> It's been professionally rewarding, providing me with a framework to contact other researchers who I might not otherwise talk to. (Scientist, Phase III)

In some cases, NASA SS educational programs were designed to yield actionable data. This provided direct benefit to researchers, whose careers are affected by how much data they can gather, analyze, and publish.

> It's the first educational program I encountered where they said one of their goals was to do publishable science. (Scientist, Phase IV)

> It seemed like they could help me out by collecting data more frequently than I could at an observatory. (Scientist, Phase III)

CULTURAL SHIFT

The culture change within NASA had an impact on the larger scientific community, which began providing more formal recognition of scientists' educational contributions;

this is particularly important for younger scientists who want to move forward in their field.

> I think the community is seeing the importance of using space science as the way to grab young people's attention, just to get them turned on to science, math, and engineering, in general . . . It's working better and better as time goes on. (Scientist, Phase III)

As the system expanded, members of the NASA SS E/PO Effort recognized the need for criteria and tools to assess the impact of the resources and programs it created. Each Forum dedicated either internal staff who are expert in assessment or outside consultants to assess their products. In addition, some larger missions had dedicated assessment staff. Forums, programs, and missions with trained assessment staff instituted regular assessment and user feedback, which provided them with the information needed to create effective resources that meet user needs.

> We have a product review system. We look for what's good, where are the gaps. We do our own internal review . . . Two aspects of review: Give it to teachers and see what they think of it. What grade level would they use it for? Would they use it in the classroom? Then give it to scientists, make sure it's up-to-date and accurate. (SN member, Phase III)

Those directly involved in the SN reported that their participation greatly influenced the way they approach E/PO. They indicated that they were more invested in education and believed that they had stronger skills and a better understanding of user needs.

> I think I'll incorporate it into any future things I do—all the things I've learned. So when I go ahead and create or upgrade materials, I will keep in mind the different populations that will be seeing these. I used to have a narrow mind about the populations I was targeting. I think I'm much broader now. I'll be more aware of the adult population, like the teachers. (SN member, final phase)

> To me, that was the most significant part of it. Being part of such an amazing group with so many ideas, so much knowledge. Probably the single most important professional experience I've had, growth-wise. (SN member, final phase)

> I learned from colleagues. I'm stronger in some areas, and they were stronger in others. We created a body of people who could learn on the job. I give credit to the Ecosystem for ongoing professional development. (SN member, final phase)

In particular, several SN members reported that their involvement with the Effort had given them an appreciation for evaluation and assessment.

> One of the crowning achievements of the OSS program is that they had an independent evaluation group looking at the whole system. That has not been the case for NASA's overall program. I think we brought in a culture of evaluation that, at least on paper, is being recognized by NASA's overall program. (SN member, final phase)

> Evaluation has made a huge difference. Learning what that means and how to do it. (SN member, final phase)

Some SN members expressed the belief that the NASA SS E/PO Effort has provided a model for NASA's Office of Education. They reported that they recognized aspects of the NASA SS E/PO model in other areas of NASA education, and that they believed this to be a good thing.

> It changed from being viewed as an upstart to being a model. There's a certain amount of emulation. It's more . . . colleagues' verbal statements. Their comments of respect. ESMD[15] is probably influenced by SMD's E/PO Effort. SMD E/PO programs were expected to operate at a high level, and were evaluated to see that they were. The new administration of NASA adopted those expectations, and guidelines like building partnerships, sustainability, addressing diverse audiences, involvement of [scientists in creating] the science content. (SN member, final phase)

> The other piece that goes with audience needs is the increased emphasis on evaluation and the need for authentic data. I think that's changing across NASA. It's not just a numbers game, and that's a good thing. I think it's largely due to the Ecosystem. (SN member, final phase)

> I think there are individuals within the Office of Education who came in with little awareness of the Ecosystem and that has grown over time. They have an appreciation of the depth and richness of what the Ecosystem has built. (SN member, final phase)

FORMAL EDUCATION

INPUT FROM TEACHERS

The NASA SS E/PO Effort built upon NASA's commitment to formal education by working with teachers themselves to develop resources that have impact in the classroom. Although classroom teachers had been traditional recipients of NASA E/PO resources, data suggest that they were better served through the Effort's new approaches.

> A lot of missions were known to put together shiny lithographs and huge notebooks of content that didn't go over well with educators. And over time, with collaboration between educators and scientists, I've seen more classroom-ready materials come out, and really interesting in a way I think that a lot of teachers are hungry for. (SN member, final phase)

> As the resources have gotten better, the response has gotten more favorable, and as access has gotten better (e.g., website, deal with Office Max so teachers can

[15] Exploration Systems Mission Directorate, part of NASA; more information at http://exploration.nasa.gov/

> get things easier) the response has gotten more favorable.
>
> (SN member, final phase)

Resources were developed for formal education incorporating both current research on pedagogy and user feedback about the type of resources that contribute most effectively to learning. Audience members identified a range of NASA SS resources that were particularly effective in meeting their needs. These include:

- Activities based on the scientific method, especially those that encourage students to raise their own questions and conduct experiments to address these questions

  > [My students] are getting a better understanding of how science works and what it is, and much more confidence in their ability to *do* science.
  >
  > (Teacher, Phase III)

- Resources that provided opportunities to engage in authentic research, including collecting and analyzing live data

  > I was particularly interested in collaboration efforts with real scientists and participating in real research. (Teacher, Phase III)

- Activities that are developmentally appropriate for learners of different ages and with different levels of readiness to learn space science content, and resources that can be altered by educators to meet the needs of different populations

  > I adapted [activities designed for younger students] for my students; it was easy to do. The labs for younger students provide a lot of information. I took some of the information out and had the students do their own research on the Internet. (Teacher, Phase III)

DIRECT INTERACTION WITH SCIENTISTS

One of the fundamental principles of the NASA SS E/PO strategy was the bringing together of scientists and educators. Formal education resource development teams were composed of both scientists and teachers. Data indicate that when scientists and teachers develop resources together, each brings their own expertise: scientists bring their understanding of scientific content while teachers bring their understanding of student needs resulting in higher quality educational products. The SN worked with scientists and educators to ensure that all parties had realistic expectations of participation and were able to make meaningful contributions.

> Seemed like if we wanted to develop lesson plans that teachers could use, we would need a teacher . . . best way is to work with teachers to develop these types of things that I certainly don't know how to do. Also get a teacher's perspective on what would be useful and the kinds of things those students would find interesting. (Scientist, Phase IV)

> We now look for opportunities to get more input from other people, or collaboration with other groups, and I think that has improved all of our products. The sound of one hand clapping is nothing. (SN member, final phase)

Both scientists and educators were involved in panels responsible for reviewing E/PO proposals, products under development, and existing products. Thus, end users had the opportunity to give input at all stages of development.

> Input from users is increasing—this leads to resources that better meet user needs, as well as more buy-in from audiences. We ask them what they want. That makes it a whole lot easier to provide products. It also makes people want to work with you. (E/PO lead, Phase III)

The NASA SS E/PO Effort supported programs that had scientists work directly with teachers and students, either in classrooms or in research facilities. These experiences were beneficial to all parties involved.

- Scientists reported that formal education experience gave them direct information about what teachers and students need and want, which helped them understand how they can use their time and energy to make the most significant contributions.

  > I have a better sense of what does and doesn't work in the classroom because I have contact with teachers. (Scientist, Phase III)

- Data indicate that students found meeting scientists to be exciting and motivating.

  > It was interesting and fun to contribute to something so big and work with an actual scientist. (Student, Phase IV)

  > [The program] has given them a more positive attitude about science and boosts their morale as far as . . . it made them feel special because they got a weeklong field trip and met actual scientists. The scientist came to our school and met their parents and teachers; made them feel special. (Teacher, Phase IV)

- Teachers reported that meeting scientists in person helped humanize people in the profession.

  > They're people! [A scientist] has come to class and students ask him questions. It's amazing; he's a person just like me. (Teacher, Phase III)

In addition to providing useful data for scientists, as discussed on page 15, the education model of including real data collection makes the experience more meaningful for teachers and students.

> I like that we were doing something that actually mattered, not something pointless. (Student, Phase IV)

> It wasn't just book knowledge. It was actually doing something real, making a contribution to something real. There was a level of seriousness to it that wasn't typical. (Teacher, Phase IV)

Students reported that engagement in actual research allowed them to better understand what scientists do. This in turn made them more receptive to the idea of pursuing a career in science.

> I thought scientists would just be doing experiments all the time. Now I know they do different things, like collect data and do research on specific topics they're working on. (Student, Phase IV)

> Just doing it made us more comfortable. We have a feeling of what it's like to be scientists on a radio telescope. (Student, Phase IV)

Data suggest that face-to-face interaction between scientists and teachers is rewarding for both parties.[16] Many teachers reported being somewhat intimidated by scientists, and meeting one in person brought home the humanity of people in the profession.

> They had a scientist from JPL come and talk to us, and that made it kind of personal. (Teacher, Phase IV)

ENHANCEMENTS TO PROFESSIONAL DEVELOPMENT

The NASA SS E/PO Effort supported several ongoing programs that fostered long-term relationships between teachers and scientists. Teachers involved in longer-term PD activities had the opportunity to develop activities or curriculum units specifically for their own classrooms. In some cases, scientists or science education experts worked directly with teachers in developing or adapting resources.

> We're a very informal group so we try and be very, very open to the teachers and try and meet them on even footing even though they've come to us. I don't look at it as we're some how above them. And they're trying to learn from us, but it's more of an equal type of relationship. They're trying to learn science and we're trying to learn education. (Scientist, Phase III)

> It has to be a relationship, a continuing relationship between teacher trainers and NASA. It can't be a one-time deal. (Teacher, Phase III)

Current research suggests that classroom science resources are most effectively used by teachers who have been trained in both scientific content and pedagogical methods for using the resource.[17] The NASA SS E/PO Effort responded to this research by creating longer-term PD opportunities that provided fuller support for participants, ranging from multi-day workshops to scientist-teacher partnerships that spanned several years and

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[16] Cohen, S., Gutbezahl, J., & Griffith, J. (2001). *Office of Space Science: Education/Public Outreach Phase II Evaluation Report.* Cambridge, MA: Program Evaluation and Research Group.

[17] See, for example, Duckworth, E., Easley, J., Hawkins, D., & Henriques, A. (1990). *Science education: A minds-on approach for the elementary year*s. Hillsdale, NJ: Lawrence Erlbaum Associates and Tharp, R. G., & Gallimore, R. (1988). Rousing minds to life: *Teaching, learning, and schooling in social context*. New York: Cambridge University Press.

included interactions between the scientist and students, such as classroom visits from the scientists, or class field trips to research institutions.

> Understanding that you need a long-term experience. It could be a week or two weeks. More than a day. That you are exploring not just: "Here are a bunch of activities, now go!" But you're looking at the misconceptions in the people at the workshop, and the misconceptions that their students may have. You're interweaving the learning with interactions with real live scientists, and engaging in inquiry-based activities. It's a lot to do and it requires a lot of time. And you need to keep in touch and see how they're doing over time.
>
> (SN member, final phase)

To support teacher learning, the NASA SS E/PO Effort increased the number and variety of workshops it provided, including several that targeted areas such as serving students with special needs, engaging students from traditionally underserved populations, or building partnerships between educators and scientists. Teachers who benefited from NASA SS -supported PD helped increase the impact of NASA SS E/PO resources by sharing their knowledge and understanding of space science with their students.

> Our main focus now is increasing our impact. Making sure our materials and activities are useful to teachers. We're now focusing on teacher and educator PD. It doesn't help to have something good if teachers don't know how to use it. If they don't know how to use it, they'll be afraid of it. It will sit in a drawer somewhere. (SN member, Phase III)

> I received extensive knowledge into space and science. It filtered on down through the scientist into my classroom. (Teacher, Phase III)

> I have gone to all the product review workshops; they tell us instead of just giving things out, teach them how to use them. Studies show that people use the thing they learn to use in workshops. So rather than giving them a mess of resources, I'd give them a few, but show them how to use them, to ensure they'll be used. (SN member, final phase)

Teachers reported that involvement in NASA SS E/PO PD increased their confidence in their ability to teach science, provided them with useful skills and resources, and made them excited to share NASA resources with their students. They indicated that the training they received allowed them to effectively integrate resources into their classrooms.

> The teachers that we've been working with—I see that 'Aha!' look in their eyes; their engagement. They didn't want to stop. They just keep coming back with more questions. (SN member, final phase)

To maximize the effectiveness of teacher PD, the NASA SS E/PO Effort leveraged existing networks of teacher-leaders. These leaders attended NASA SS workshops and shared the knowledge and skills they developed with teachers in their own schools and districts.

> What NASA needs to do is support and continue to excite a cadre of people around the country who will go out there and get that message out.
> (Teacher, Phase III)

> If you train them, they train teachers in their states. We establish networks to increase the size of our audience. Getting more science to the teachers, so they'll use more. (SN member, Phase III)

Several teachers who participated in NASA SS -supported PD programs said they took on leadership positions. This enhanced their professional status as well as providing further dissemination of NASA E/PO resources.

> I've shared with professional groups; I've shared at college symposia where you talk about what you do with new teachers. Within my own teaching area, I've tried to draw in my colleagues. (Teacher, Phase IV)

FORMAL EDUCATION RESOURCES

The NASA SS E/PO Effort provided support for the development of printed resources such as posters, litho sets, and bookmarks that bring the latest images of space into classrooms. The Effort reached out to institutions with limited technological capability through 'low-tech' resources such as paper-plate astronomy and other educational activities that use common items, such as candy bars, tennis balls, and Styrofoam. These resources and activities were widely disseminated through web pages and workshops. Data indicate that teachers appreciated these resources, which fit in with the limited time and budgets at their disposal, and used the resources in their classrooms.

> They had a lot of hands-on applications, yet it was easy to get the point across, and using common cheap items. (Community educator, Phase III)

> I have a lot of print material, posters, supplies, kits of different things I would not have gotten if I was not part of [an NASA SS E/PO program]. It helped me improve my classroom environment. (Teacher, Phase IV)

The NASA SS E/PO Effort produced developmentally appropriate resources for learners at different ages and levels of preparedness to learn space science content. Data indicate that students responded very positively to NASA material, finding it exciting and engaging.

> [Students] are very excited about it, very serious. The anticipation is great. They think it's cool. (Teacher, Phase IV)

> I learned about space and comets and Mars and it was good. (Student, Phase IV)

The NASA SS E/PO Effort developed, supported, or impacted a wide range of formal education programs that embodied the user-friendly qualities discussed above. Some examples are:

- **Mars Student Imaging Project:** Teams of students in grades 5 through college sophomore level work with scientists, mission planners and educators to image a site on Mars using the visible wavelength camera onboard the Mars Odyssey spacecraft. The curriculum was developed to align with National Science Education Standards and fit within existing science curricula. More information about the Mars Student Imaging Project can be found at http://msip.asu.edu/.
- **SUNBEAMS**: Students United with NASA Becoming Enthusiastic About Math and Science (SUNBEAMS) is a partnership between a NASA center and the Washington, DC public school system. The program pre-dates the 1995 Implementation Plan, but the NASA SS E/PO Effort supported and fostered the growth of the program. As part of the program, teachers spend five weeks working with a scientist mentor. During the following school year, each teacher implements a curriculum they develop based on his or her experience, the scientist mentor visits the teacher's classroom, and students spend a week visiting a NASA center. Data indicated positive impact on scientists, teachers, students, and the Washington, DC community. More information about SUNBEAMS can be found at http://hesperia.gsfc.nasa.gov/~gilbert/sunbeams/SB%20Prog%20Page.htm.
- **The Chicago Teachers' Advisory:** One B/F achieved success by partnering with teachers in Chicago to determine their needs and develop ways to meet them. Over the past eight years, the B/F hosted 14 symposia and more than 40 workshops, reaching more than 600 teachers across four states in their local region. In addition to functioning as a professional development for teachers (creating high-leverage opportunities to disseminate information to teachers and students), the relationship between the B/F and local teachers allowed for information to flow from the teachers into the SN. This provided valuable data about teacher needs and constraints, and informed the way that the SN provided resources for formal education. More information about the Chicago Teachers' Advisory can be found at http://ossim.hq.nasa.gov/ossepo/2002/Res8946.html.
- **Sun-Earth Day:** One of the Forums created a series of programs and events that occur throughout the year and culminate with a celebration on or near the Spring Equinox ("Sun-Earth Day"). These programs are supported by a variety of resources including a website, print resources, and various multi-media products. Over the six years since the first Sun-Earth Day, the program has grown substantially and now serves classroom teachers and students, informal venues, community groups, amateur astronomers, and others. Personnel involved in Sun-Earth Day say that demand for resources has grown: they create 15,000 resource kits each year, which are quickly disseminated. They also receive a great deal of informal positive feedback from participants. More information about Sun-Earth Day can be found at http://sunearthday.nasa.gov/.
- **Modeling the Universe:** One Forum created a suite of hands-on activities and inquiries related to current models for the origins and evolution of the universe. These activities are shared with 8^{th}–12^{th} grade teachers at workshops where the teachers receive content and pedagogical training, as well as classroom-ready materials supporting each activity. After completing the workshop, teachers have access to a webpage and wiki, which contain additional materials and support.

The program is aligned with federal and most state standards. More information about Modeling the Universe can be found at http://cfa-www.harvard.edu/seuforum/mtu/.

INFORMAL EDUCATION AND PUBLIC OUTREACH

CREATING ENGAGING RESOURCES

Data suggest that NASA materials are especially well suited to informal education venues, where they are effective at engaging learners and sharing the excitement of space exploration.

> We may need to ask ourselves: Why are we interested in science museums? Besides the fact that they're fun places, they're engaged in systemic reform. We know that about half of science is learned outside of classrooms. This is another high leverage opportunity; 92 million people a year visit science museums. (SN member, Phase I)

> I'm thinking more and more that the appropriate place for space science is in the informal venues and afterschool programs, where teachers are less constrained by the standards. I think it takes a lot of effort to create a successful afterschool program, but I think that's where we can have impact. (SN member, final phase)

The NASA SS E/PO Effort provided access to current, ongoing research that could be incorporated into existing programs and resources. They effectively leveraged the knowledge and expertise of the museums and science centers to create resources that better meet end user needs.

> Now they are supporting a whole range of programs that museums come up with. They have access to scientific research, images, and so on. Things can come out of that. (ASTC member, Phase III)

Museum staff reported that NASA SS resources and NASA's strategy of involving scientists in educational resource development are effective at engaging and educating visitors.

> [The exhibit] was successful in making something static come alive. (Museum staff member, Phase III)

> Over the three months [of the exhibit], our attendance increased 100% over the previous year. (Museum staff member, Phase III)

> For me and the content development, it's made all the difference in terms of the richness of the content we have access to. There's no substitute for talking to scientists about the things they're passionate about. It's interesting that you take this very intellectual scientist, scratch the surface, and find this passion about what they do. (Museum administrator, Phase II)

RESPONDING TO END USER NEEDS

Information from end users and experts provided the E/PO Effort with information about the needs and constraints of the various types of informal education institutions, allowing for the development of more effective resources.

> In developing programs or materials, first we figure out what the product will be used for—that makes a big difference. (E/PO lead, Phase III)

> For informal education, the fact that it's so large and so diverse. Everybody has a different flavor so you have to do a lot more tailoring to the individual needs. (SN member, Phase III)

The NASA SS E/PO Effort developed flexible and adaptable traveling museum exhibitions. The Effort responded to the needs of both large and small venues by creating differently-sized and -priced exhibits using similar content. For example, the NASA SS E/PO Effort supported two museum exhibits based on current Mars data. *MarsQuest*, and extensive exhibit appropriate for large venues, and *Destination: Mars*, which addressed many of the same educational issues, but was designed for venues with limited size and budget. Similarly, two versions of the *Hubble Space Telescope* exhibit met the needs of a wider range of venues.

Thanks to active participation in organizations such as the Great Lakes Planetarium Association (GLPA), there is a growing network of small to midsize museums around the country that benefit from the work of NASA SS E/PO.

> There are about 1,500 planetariums in the US. They're on shoestring budgets and they have great ideas for neat projects. They have up to 40,000 visitors a year, and they are lacking just a few hundred dollars to carry these projects out. (SN member, Phase II)

Projects such as Space Place, a program to distribute SS E/PO resources to a variety of institutions (described more fully on page 27) provided high-quality, inexpensive materials to smaller venues that reach audiences who may not otherwise have access to space science materials.

> The bulletin board is an excellent addition to our museum and to the programs we design for teachers during the school year and for our summer program. It helps me do the research I need to stay current and design space exhibits. (Museum staff member, Phase III)

REACHING THE PUBLIC DIRECTLY

The NASA SS E/PO Effort expanded its public outreach to include resources at public spaces; for example, a permanent scale model of the solar system on the National Mall in Washington, DC and traveling exhibitions at shopping plazas and theme parks reach a population beyond those that are exposed to space science in school or at museums.

In addition to supporting small science centers and museums, Space Place provided materials to amateur astronomers who work with young learners. These astronomers encourage children to use Space Place resources and continue to explore space science on their own. Data suggest that Space Place materials are effective at exciting young learners.

> [Space Place materials] open the eyes of children to the wonder of space and science. Who knows where they will go? (Amateur astronomer, Phase IV)

> It's something the kids for sure can relate to. They are interested in science, astronauts, and future careers. (Amateur astronomer, Phase IV)

The amateur astronomers expressed appreciation for materials that NASA SS provided to them at no cost.

> [The biggest benefit to our club is] all the free material to help promote astronomy and the space sciences. It's extra nice that the material is so current and topical. (Amateur astronomer, Phase IV)

LEVERAGING NETWORKS

The NASA SS E/PO Effort leveraged existing networks to spread information, including posters, litho sets, and planetarium shows that brought the latest images of space into museums, science centers, and other venues. Data suggest that these resources are effective at sharing current, accurate scientific information with the public.

> The thing that NASA has a handle on better than anyone else is that they have the most up-to-date images and information. (Museum staff member, Phase III)

The NASA SS E/PO Effort partnered with leaders within networks of users, individuals who share the knowledge they receive at workshops with other community group leaders, librarians, etc. Disseminating SS E/PO information through these leaders increased the reach of workshops and other PD. Moreover, as members of the audience being served, the leaders had firsthand experience that allowed them to be responsive to audience needs.

> Having [Girl Scout leaders] sharing the activities they have . . . [with] the girls can be real enlightening for [leaders who did not have direct experience with NASA personnel], and the 40 of us who came [to the workshop] are representative from all over the US. [Using GS leaders to share space science information] would help to make the transition—those guys are from NASA and they are not [members of our community]. (Community group leader, Phase III)

> Most of us were very pleased with the presentation of the workshop; [the staff from NASA] didn't make us feel dumb or inadequate; we were amazed at some of the things. (Librarian, Phase III)

Several B/Fs developed and fostered partnerships with pre-existing networks of libraries, small science centers, and community groups. The NASA SS E/PO Effort connected scientists with these networks, providing support and expertise for the development of better scientific understanding among network members. These networks reached into rural and urban areas that had been underserved by more traditional space science resources and have provided materials and professional development to allow librarians, science center staff, and community group leaders to better educate their audiences.

> I think it's a wonderful way to excite the kids and open their minds to other possibilities. This is a rural area, and kids don't go towards this type of science field. (Librarian, Phase III)

> I'm seeing more astronomy programming being offered, whether it's looking at constellations . . . We have an astronomy club of high-schoolers who teach astronomy to elementary kids. (Community group leader, Phase III)

INFORMAL EDUCATION AND PUBLIC OUTREACH RESOURCES

The NASA SS E/PO Effort developed, supported, or impacted a wide range of programs that successfully meet the diverse needs of informal education institutions and engage the public, as discussed above. Some examples are:

- **The *Cosmic Questions* Exhibition:** *Cosmic Questions* was a 5,000-square foot interactive exhibition, designed to promote reflection about the 'big questions' regarding the structure and evolution of the universe, and humanity's place within it. The exhibition included creation theories from a number of belief systems, as well as up-to-date information about the universe. *Cosmic Questions* was designed to encourage visitors to construct meaning and find relevance in the scientific material presented. Data from visitor studies suggest that both museums and visitors were positively impacted by the exhibition. More information about *Cosmic Questions* can be found at http://www.nasa.gov/audience/foreducators/informal/features/F_Cosmic_Questions_prt.htm.
- **Project Explore!** Project Explore! was a cooperative project engaging libraries as partners in providing community access to NASA educational resources. Materials and activities were developed by NASA SS E/PO staff in collaboration with library personnel and support from NASA SS scientists. These materials were used in afterschool and summer library programs aimed at difficult to reach preteen audiences (ages 9–12). Data suggest that librarians found the program engaging and that it was successful in sparking interest among preteen and teenage patrons.
- **The Space Place:** The Space Place was developed with the goal of raising elementary school children's awareness of and enthusiasm about space and Earth science. The Space Place distributes resources, such as posters, lithographs, and hands-on activities, to community partners (museums, libraries, aquariums, children's centers at military bases) who display and share these resources with young visitors. The Space Place provides children's science columns to Spanish

and English language newspapers, and writes copy for astronomy club newsletters geared toward members who want to reach young minds. The Space Place reaches young learners through its website and through its partnerships with the Cub Scouts and Girl Scouts of America. Data indicate that Space Place materials are engaging, easy to use, and appropriate for their audiences. More information about Space Place can be found at http://spaceplace.nasa.gov/en/kids/.

- **The NASA/Girls Scouts of the USA Partnership:** The NASA SS E/PO Effort began working with the Girls Scouts of the United States of America (GSUSA) with the goals of raising the science comprehension of girls and women and encouraging girls and women to pursue STEM careers. Data indicate that the partnership has grown and deepened over time, reaching a large number of both adult and girl members of GSUSA.
- **Solar System Ambassadors**: The Solar System Ambassadors Program is a public outreach program designed to work with motivated volunteers across the nation. These volunteers share information about space exploration missions and information about recent discoveries to people in their local communities. Ambassadors are professional and amateur space enthusiasts from various walks of life who are interested in providing greater service and inspiration to the community at large. The Solar System Ambassador Program has a presence in all fifty states, as well as the territories of Guam and Puerto Rico. More information about the Solar System Ambassadors can be found at http://www2.jpl.nasa.gov/ambassador/.

UNDERSERVED COMMUNITIES

As discussed on page 52, the NASA SS E/PO Effort made great efforts to reach individuals that had not been served by traditional space science educational resources.

THE MINORITY UNIVERSITY INITIATIVE AND THE MINORITY UNIVERSITY AND COLLEGE EDUCATION AND RESEARCH PARTNERSHIP INITIATIVE

OSS worked with MURED[18] to create NASA's Minority University Initiative (MUI), a program to fund space science opportunities for students and faculty at minority institutions. MUI guidelines encouraged funded minority institutions to partner with other science research institutions, such as research universities and NASA centers. One component of the program involved the development of projects to provide outreach to the larger minority communities in which the funded institutions were situated; approximately one-third of the participating minority institutions included outreach as part of their MUI-funded activities.

[18] NASA's Minority University Research and Education Division.

By promoting partnerships between minority institutions and other research facilities, the MUI supported the creation of a network of minority and non-minority researchers. This provided the mainstream research community access to input from minority researchers, and benefited underserved communities in a variety of ways, including the following:

- The minority institutions participating in the MUI reported a variety of successful outcomes that have the potential to impact all members of the university community.
  - All MUI recipients either created new, or significantly increased existing, programs in astronomy and space science.

    > It's improved the delivery of science here. Before, we had astronomy on the books, but it was never taught. (MUI recipient, Phase III)

    > We've set up a university-wide degree program in astronomy. We also initiated minors at various campuses. (MUI recipient, Phase III)

  - Some minority institutions used MUI funding to create and improve space science facilities, many of which lasted beyond the grant period.

    > We are now looking at our new Science and Technology building that will open next month. (MUI recipient, Phase III)

  - Faculty members reported being invigorated and excited about working with NASA scientists.

    > Professionally, I'm having the best time of my academic life. (MUI recipient, Phase III)

  - Several undergraduate students have changed majors and/or decided to pursue a graduate degree related to space science, attended the NASA Academy programs (including the first student to attend from a Tribal College), or attended national conferences where they presented their own research.

    > In at least two or three cases, [programs supported by the MUI have] provided an impetus for students to pursue a science career. (MUI recipient, Phase III)

- Several of the programs supported by the MUI included outreach into the K–12 community, either through teacher education programs or through programs that directly involved K–12 students. For example:
  - One institution developed a Saturday program for high school students.
  - One institution funded a laboratory that provides K–12 curricula for community students.
  - Several institutions developed or enhanced existing programs for preservice science teachers. At least one provided workshops for in-service teachers.

> We had a [PD for in-service teachers] workshop for the second largest middle school in the state. All but one of their science teachers came.
> (MUI recipient, Phase III)

- Some MUI-funded institutions impacted underserved minority communities through outreach activities beyond formal education.
  - One tribal college used some of its funds to purchase space science books for the reservation library.
  - The MUI provided funding for professors to speak at local planetaria, reaching interested community members. Because scientists at MUI-funded institutions are usually members of the underserved communities themselves, they act as role models.

> Being a speaker in the community, I'm able to go out to community activities and raise awareness. I'm African American and I find myself a spokesperson to raise the awareness of our students.
> (MUI recipient, Phase III)

  - Through partnerships supported by the MUI, faculty educated themselves about current space science events, and have shared information on events such as eclipses and launches to capture the public's interest.

> We reach a very different audience. We were interviewed by the "freebie" papers—those have a very large, different audience from the more elite papers like the *New York Times* and the *Washington Post*.
> (MUI recipient, Phase III)

Partnerships between researchers at minority institutions and those at mainstream science research institutions proved an effective first step toward making space science accessible to underserved communities. Because the MUI PIs were situated within the underserved communities the program was meant to support, they were able to tailor classes and activities to meet the communities' needs more effectively than a scientist outside the community could.

> Most mainstream science courses are grounded in mainstream culture. If you're not attuned to the culture you are at, you don't realize that science is not culturally neutral. All cultures have within them levels of knowledge.
> (MUI recipient, Phase III)

The process of integrating students and faculty from minority institutions into the mainstream of space science research provided opportunities and motivation to individuals who have traditionally been underserved by the scientific research community.

> We've found that there is nothing better than sending a scientist [to speak with students]. It needed a personal connection where the scientist went out and said, "Yes, I'll take you as my student." (Professor of color, Phase III)

At the completion of the first MUI grant period, OSS and NASA's Office of Education funded a second program (the Minority University and College Education and Research Partnership Initiative in Space Science or MUCERPI). Previous grant recipients could apply, provided that they proposed major extensions of the work already funded or new directions of development. Two-thirds of the institutions that had been funded by the MUI were also funded by MUCERPI, allowing them to build on work funded by the MUI. Current awardees will be completing their efforts in 2007. Most of the MUCERPI universities plan to seek funding through future NASA opportunities.

STRATEGIES FOR REACHING UNDERSERVED POPULATIONS

Science museums and centers provided a venue for underserved/underrepresented (U/U) communities to access space science materials. In particular, many colleges and universities have affiliated science museums. For historically black colleges and universities (HBCUs), this is a powerful resource for disseminating information to a population that may have little access to space science material.

> When we visited [an HBCU], we realized there was an underutilized resource [the associated museum] that could be a strong way in—not just to the university, but to the community as a whole. (SN member, Phase I)

The NASA SS E/PO Effort supported PD for scientists and E/PO developers working with underserved populations, such as Native Americans and learners with disabilities.

> I think I'm much more aware of areas of education I've never considered, like doing the Native American astronomy conference. When you teach Native Americans, you realize it's unacceptable for someone to ask a direct question. So obviously the way you approach education for these people has to be aware of that. The other is the Exceptional Needs Workshop—thinking about how different people have different abilities and what you need to do if you want them to be part of your education audience. (SN member, final phase)

RESOURCES FOR UNDERSERVED COMMUNITIES

The NASA SS E/PO Effort developed, supported, or impacted a wide range of resources that are effective at reaching underserved populations and have the attributes discussed above. In many cases, these resources were developed for both mainstream and underserved audiences, but were developed in concert with members of underserved communities. Thus the resources are appropriate for multiple audiences. In addition, the NASA SS E/PO Effort has created some resources specifically for underserved populations. Some examples are:

- **ENWS:** One of the B/Fs developed an Exceptional Needs Workshop (ENWS). For the past six years, the ENWS has brought together individuals from the NASA space science E/PO community with formal and informal education and communities of persons with disabilities to share expertise and develop ways to

make space science resources accessible to persons with disabilities. Participants attend a weeklong workshop each summer, where participants learn about persons with disabilities through hands-on experiences, learn about space science content and provide feedback on NASA space science E/PO materials. Data indicate that ENWS participants are likely to develop awareness about how to interact and engage with persons with disabilities, increase their understanding about how to create accessible experiences, and incorporate these ideas and resources into their own work. More information about ENWS can be found at http://serch.cofc.edu/special/workshops.htm.

- **Chicago 2004: A Workshop to Foster Broader Participation in NASA Space Science Missions and Research Programs** In 2004, the NASA SS E/PO Effort hosted a Workshop to Foster Broader Participation in NASA Space Science Missions and Research Programs, aimed at seeding personal contacts among a more diverse community than had traditionally been active in NASA space science missions. More than 100 individuals participated in the workshop, and over half (54%) of these identified as members of underserved groups. Almost all participants reported that they made contacts at the conference, and a follow-up several months later indicated that several partnerships were beginning to develop, many across underserved institutions and mainstream institutions with more resources. Participants reported that they found the workshop useful, and about one-fourth suggested that additional workshops be held to leverage and enhance the effects of the first workshop. More information about Chicago 2004 can be found at http://analyzer.depaul.edu/Chicago2004/.

STRATEGIES FOR GROWTH

The impact of the NASA SS E/PO Effort, described above, is even more impressive in light of the myriad challenges faced by the system, both at its inception and throughout its tenure.

At the inception of the NASA SS E/PO Effort, there were many disparate SS E/PO activities throughout NASA. These activities were supported by staff who had a range of time and energy to devote to them, and reflected a range of depth of understanding of pedagogy and user needs. Many high-quality materials had been supported and created, but there were few methods in place to identify resources that were most likely to meet user needs. In addition, lack of communication among resource developers led to redundancies and gaps in the universe of NASA materials available to educators and learners. As the SN tried to coordinate these activities, they found themselves struggling to create coherence. Creating a unified whole was a challenge throughout the duration of the Effort.

> Before, there were a few scattered approaches to share space science discoveries with the public. Then came the development of the Forums and Brokers, and an infrastructure to facilitate science in education, and embed it in missions in a coherent way. I think it made the effort systematic throughout the enterprise. It elevated the effort by several orders of magnitude. It's now reaching millions. There are partnerships with museums around the country, a coherent effort throughout the SN. It made education part and parcel of what SMD did. It was incredible impact. (SN member, final phase)

> When the SN first started, NASA Education was like the Wild West; everyone was making posters and pins, doing their own thing. [The AAA for Education] made it professional, more serious. This was because of the funding, the expectations, and support from HQ. There was guidance and direction. The formation of that whole system that was put in, it set the stage. It was beautifully done. They thought of the structure and gathered talented professionals to implement it and figured out how to live up to standards.
>
> (SN member, final phase)

GOALS AND ROLES

The NASA SS E/PO Effort addressed the challenges of creating a new approach to E/PO, and maintaining a coherent vision through a number of administrative and programmatic priority changes, by adopting a variety of strategies including:

- Maintaining a flexible and adaptive structure (as suggested by its original name, "the Ecosystem")
- Utilizing and responding to a range of evaluation and assessment techniques
- Responding to feedback from within and beyond the SN
- Promoting effective communication across all components of the Effort, and among SN members, the rest of NASA, and various end users and stakeholders

GOALS

The initial set of goals was multi-faceted, comprising four Goals and eight Operating Principles,[19] which were used to derive nine Implementation Principles, each of which had between three and six sub-principles.[20] In addition, there were various criteria developed for evaluating proposals submitted in response to Announcements of Opportunity (AOs) and NASA Research Announcements (NRAs). The guidelines in the various documents were not always aligned with one another, leading to confusion on the part of those trying to meet them.

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[19] *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs, 1995*, p. 3

[20] *Implementing the Office of Space Science (OSS) Education/Public Outreach Strategy,* 1996, p. 13.

> We shouldn't have so many goals; things get blurred. We should have three or four goals. (SN member, Phase I)

In response to the comments from SN members, and feedback given in the first evaluation report, the leadership of the Effort, in conjunction with the SN, revamped the goals considerably. The 2000 Implementation Plan contained three goals,[21] which guided the system until NASA's Office of Education developed a set of goals that superseded the NASA SS goals. The administrative changes and evolution of goals posed some challenges for the NASA SS E/PO Effort.

> For the past few years, we've been either headless or under a new head. All of that mattered so much. It's kind of hard to know what NASA itself valued, because there was so much flux. What has really struck us in the past couple of years is how little direction we can get. When we ask the people at NASA, "What should we do?" they don't seem to know. (SN member, final phase)

> I personally don't understand, other than the change of administration, what's going on in terms of underlying philosophy. Some organizations have a strategic plan for five years; that hasn't been the way at NASA at all.
> (SN member, final phase)

Programs and resources developed while the goals were in flux articulated their own objectives. Despite the challenges of coordinating pre-existing resources with new guidelines, many resources have been brought successfully into alignment with the current goals.

ROLES

In the first few years of the SN, several members expressed confusion and/or frustration about the scope and complexity of their work. They named a number of conditions they felt were challenging their ability to accomplish their purposes, but they continually expressed and demonstrated commitment to the Effort and did not doubt their capacity to be successful in many, if not all, aspects of their E/PO work.

> I felt overwhelmed at the first meeting, trying to observe the network and note the team. My primary job has been working with discipline scientists and getting them to understand the Ecosystem. The first time I came, I was shocked by all the progress. I can take these accomplishments to the scientists. A lot has happened—a lot of synergy, fellowship; I feel very comfortable.
> (SN member, Phase I)

The Forums, which aligned with the four space science themes utilized at the time of their development, were tasked with collecting data from the missions associated with their theme. Initially, some missions were hesitant to cooperate with the Forums, and SN

[21] *The Space Science Enterprise Strategic Plan, 2000*, p. 23.

personnel were pro-active in forging strong relationships with the scientists in their theme.

Broker/Facilitators (B/Fs) were tasked with providing support to scientists and educators in their geographical region, and with helping to build partnerships. They were not supposed to create, or help create, resources or proposals.

> The Brokers are supposed to identify the projects [and other resources], but they are not supposed to get involved in actually creating the products.
>
> (SN member, Phase II)

> Suddenly this whole thing of outreach was to look with a new vision about what NASA has to offer K–12 and informal education. And say what's a good fit for the needs in our region. That's a very different way of looking at things than pushing things out to get numbers. So I thought it was very exciting, and that I could start looking at things I hadn't been aware of before.
>
> (SN member, final phase)

The B/F role was new to NASA; their activities did not always align with existing structures for tracking and reporting and there were no pre-existing criteria against which they could be measured. The B/Fs faced significant challenges in communicating their activities in a way that was meaningful to the rest of NASA.

> The Broker program didn't develop a common set of metrics for ourselves and those outside that would evaluate our performance. And we were on the verge [of realizing that] and didn't have time to fully understand that.
>
> (SN member, final phase)

> Look at the reporting system: everyone has to use NEEIS[22]. It felt like an inventory and we needed do an evaluation based on our core functions. One was much more conceptual and strategic, and the other was basic: What did you do? How did you do it? And how many times? (SN member, final phase)

Several Education Council members (at both Forum and B/F facilities) expressed concern that B/Fs did not have a clear understanding of the system standards that would be applied to determine their success or failure. This continued to be an issue of concern throughout the life of the SN, and was mentioned in the PERG evaluations, the Task Force Report, and the Senior Review report.

Some B/Fs consulted with the evaluators and developed matrices of activities. These matrices helped these individual B/Fs in assessing their own work, although they did not contain system-wide criteria for assessing their roles within the system.

To help clarify the roles, goals, and criteria for success, the Education Council arranged a number of Forum and Broker retreats, as well as meetings of individual institutions

[22] NASA Education Evaluation and Information System, an online system for tracking NASA Education activity.

within the system, to improve communication and clarify roles. Data indicate that over time, the NASA SS E/PO Effort developed a clearer understanding about the roles of the Forums and B/Fs and the functioning of the SN.

> Our role has become much clearer. And we've become more known and helpful to the missions, in particular. Connections with the Forums are getting better after this past retreat. (SN member, Phase III)

Over time, the B/F role evolved. Each B/F developed its own identity, building connections within its region, and utilizing its own areas of expertise. The B/Fs grew from institutions struggling to find identity to institutions with clear goals and much to offer the E/PO community.

> A lot of the clarity I have about being a Broker evolved with time. It wasn't in the AO, or in anything that anyone told me. [There was nothing explicitly articulated] except facilitating scientists' involvement in education. We are not only doing that, but reaching out to the region, understanding the character and [what the] needs are, who's underserved and where are the organizations that are the levers to reach out and you can partner and [let them know that particular] resources will be of interest or of particular value. Done at its best, it's a sophisticated role. We are really just learning how to make it flourish. No sooner do we have it figured out than it's going away. It took time to understand how we could be at peak functioning and learn from each other as we connected among the regions. (SN member, final phase)

As the role evolved, and became better known, a larger portion of the NASA and education communities began to utilize the B/Fs. Many individuals who had previously expressed little understanding of, or interest in, education began working with B/Fs to further their own development and to create effective resources.

> Over the last three years, I've fielded more mentoring calls than ever. Some people are becoming interested in science policy or education. We started counting those up as a brokering role. That is a significant emergence of a role. (SN member, final phase)

Some B/Fs reported that they plan to continue their brokering activities after the dissolution of the SN. Many have built substantial networks and will continue to bring people together to leverage their individual expertise.

> Post-broker, I will continue connecting people. I won't be funded to be quite as proactive, but if I can be of value that way, I will continue to do so. Identifying high leverage opportunities will be useful. (SN member, final phase)

CULTURE

SCIENTISTS IN EDUCATION

The NASA SS E/PO Effort put significant time and energy into identifying and meeting the needs of scientists to allow them to more effectively contribute to NASA space science E/PO resources. Scientific involvement with E/PO gained value in the scientific community. The NASA SS E/PO Effort supported scientist involvement in education by:

- Mandating that each mission spend 1–2% of its budget on E/PO
- Providing substantial funding for E/PO
- Highlighting recognition from professional organizations
- Supporting opportunities for researchers to publish education articles in peer-reviewed journals
- Providing extensive support from experts, educators, and SN members to scientists who expressed interest in participating in E/PO

When the NASA SS E/PO Effort started, there were few structures in place to support or reward scientists working in education. Many scientists viewed the E/PO component as something extrinsic to their work: Not integral to the missions; not integral to their careers.

> As scientists, our main job is not education; we get evaluated on our projects. The education I do is purely a sense of social obligation. I enjoy it, but it's not something I see as advancing me career-wise. (Scientist, Phase I)

> We can't expect the scientists to develop the materials. We have to know how to appreciate their culture and learn how to adapt it into our approach of scientific inquiry. (Education partner, Phase II)

Traditionally, scientists and other researchers were rewarded for sharing their findings with others in their community, either at conferences or in peer-reviewed journals (the "publish or perish" mentality). The NASA SS E/PO Effort articulated the need to share information, not only with the scientific community, but also with the public.

> If all NASA missions do is fill journals with articles and win prizes for scientists, then we fail. We need to share that information about discovery with the public, otherwise we fail. (SN member, Phase I)

NASA scientists have a great many demands on their time. Mission science deadlines take priority, leaving little or no time for E/PO activities.

> Education products or endeavors are seen as a time sink by the scientist members of the team . . . If you ask [the PI], he would say he is interested in educational outreach, but in terms of what he needs to spend time on right now, it's analyzing the data. (E/PO lead, Phase III)

Being a successful scientific researcher is a full-time job; so is being an educator. Some scientists working part-time in E/PO said they saw themselves as serving two masters. Our data indicate that many scientists have difficulty finding the resources to serve both masters well.

> Scientists who work in science education run the risk of not being seen as someone doing science. They have to have intensive periods where they go to meetings, publish lots of papers, focus on the science. It's difficult to do two jobs. (Research scientist, Phase II)

> It's extremely difficult to maintain a career doing 30–40% public outreach, because you can't maintain a research career at 60%. You either have to drop down to dabbling in E/PO so you can bring in the research money, or devote yourself to being an E/PO person on E/PO money. (Research scientist, Phase II)

Scientists' believed that making meaningful contributions to education demanded a large investment of time and energy. The NASA SS E/PO Effort was able to provide them with assurance that working in education did not require them to become experts.

> One of the difficulties is you need to learn a whole new set of rules, jargon, new way of doing things. We're not sure that it's a good use of our time, because it's not our field of expertise. (Mission scientist, Phase II)

Many scientists expressed frustration with their limited understanding of the national science standards and educational pedagogy. Although many scientists said they would like to create successful E/PO products, they believed that their limited knowledge and experience would prevent them from doing so.

> There's a sort of mismatch between our skills and our training and what we're being asked to do. We can learn some but not necessarily to the 'professional' level where it can be handed off. It takes so much time to learn it; it may not be a useful expenditure of our time. (Research scientist, Phase II)

The NASA SS E/PO Effort clarified the roles scientists were expected to play and coordinated partnerships with individuals and organizations that had the pedagogical expertise needed to create quality E/PO resources. The SN provided avenues through which scientists were able to contribute their knowledge and expertise, rather than being expected to create coherent educational resources, a task better suited to educators or curriculum developers.

> Brokers can make sure that only those tasks needing scientific input are forwarded to nearby scientists. Brokers can also provide means for scientists to become involved without [scientists] having to make initial contact.
> (SN member, Phase I)

Not all scientists are motivated to make such a large investment in learning about the educational community, but want to contribute to E/PO in other ways. The NASA SS E/PO Effort created options for such scientists.

> We want to point out to active researchers that there are a lot of opportunities where they don't have to take a lot of time and they can get involved in these types of activities. We want to ally them with other individuals or groups that are already doing education and outreach. (Professor/research scientist, Phase II)

> If you want to create curriculum, it needs to be aligned with national standards. Scientists don't necessarily have time to learn all that, so there are better ways to make use of their contributions. (SN member, Phase II)

Scientists reported that their colleagues did not appreciate the value of their efforts in E/PO. This perceived lack of support for educational activity made scientists reluctant to take time away from their scientific pursuits to focus on E/PO activities. Members of the SN reported that they often faced an uphill battle when attempting to involve scientists.

The decision to devote 1–2% of each mission's budget to E/PO provided scientists with the resources to create meaningful E/PO products. Efforts to embed E/PO in the missions worked well. Data indicate that the scientific community's initial acceptance of E/PO work was related largely to funding decisions. Once there was an administrative mandate from NASA SS that each mission *must* provide resources for education, E/PO gained value in the eyes of the scientific community.

> Missions now place 1–2% of the funds for education, and it has to be *good* education. So now, if you want a mission, you better get a good education program together. So, it becomes valued. (Research scientist, Phase II)

> It was sort of a combination of carrots and sticks. The stick is: this is a policy by the agency, not a popularity contest. As an agency, NASA decided to embed education into every Space Science mission. This provided consistency, accountability and resources. The carrots are resources, and for scientists to reflect on the bigger picture of their mission: Why are we doing this? What is significant? If they cannot explain it to their own daughter, son, or neighbor… since this is taxpayers' money I think that [they need to be able to do that, if not] that's a problem. (SN member, final phase)

SCIENTIFIC AND EDUCATIONAL STYLES

Many of the NASA SS E/PO activities were built on scientist/educator partnerships. The NASA SS E/PO Effort supported these partnerships by:

- Creating multiple opportunities for scientists and educators to work together
- Allowing educators opportunities to visit and do research in scientific institutions
- Allowing scientists to visit and interact with learners in classrooms, museums, and other educational venues
- Hosting conferences to support the professional development of both scientists and educators working in space science education

One of the challenges to the NASA SS E/PO Effort was the divide between the two communities in terms of culture, philosophy, and language.

> There are problems in the different philosophies and approaches of scientists and educators. So, there's a lot of conflict that needs to be resolved. Scientists seem to think that the science should be first and we've all been educated so we know all about it. Educators think that scientists don't know anything about how children learn. Also, scientists tend to be more aggressive when they disagree with something. It's a different approach. Educators see strong criticism almost as an insult and that's not how it is meant. They can get defensive. It's a necessary learning process for everyone involved. (Mission scientist, Phase II)

> Sometimes you have educators and you have scientists who want to do the same thing; each thinks "Oh, they're nuts." (SN member, final phase)

Scientists are often unaware of the needs of teachers or of current pedagogical research. As one space scientist noted:

> We're physicists; that's our training. I doubt any of us took any education classes. (Scientist, Phase I)

Scientists working with E/PO often lacked support for their understanding of teacher needs. This led to a range of challenging conditions:

- Materials were organized to reflect scientists' understanding (i.e., missions) rather than educator needs (i.e., science content, standards).
- Resources assumed knowledge that was beyond what teachers could reasonably be expected to know.
- Resources were inappropriate for time/money constraints in the classroom.
- Resources were not pedagogically sound.

One function of the NASA SS E/PO Effort was to help scientists better understand the needs of educators.

> We have discovered a certain amount of sensitivity training helps a lot of scientists who have not heard of systemic reform, science standards. We're just informing them. Some of them have no idea of implementation of change, no idea about hands-on curriculum and so forth. The thought is to give them some experience. (SN member, Phase I)

Lack of experience with teachers led some scientists to interpret under-preparedness as an indication that teachers were unable to understand the complexities of space science. Scientists sometimes communicated their low expectations for teachers in ways that overwhelmed the educators and made meaningful communication difficult.

> Many teachers I deal with have backgrounds in music or English and they can't even describe what a day is. (Research scientist, Phase II)

> I don't know your background, so I'll assume you need to know everything. (Research scientist addressing a group of teachers, Phase II)

Educators reported that they felt condescended to by some scientists. Data indicate that teachers are less successful at learning new material when it is presented by someone they believe is passing judgment on them.

> Scientists have an attitude like teachers don't know anything. I don't need more people telling me I'm stupid. (Middle school teacher, Phase II)

By allowing scientists and educators to come together and hear about the environments under which each of them operate, the NASA SS E/PO Effort played an important role in establishing "strong and lasting partnerships between the space science and education communities."[23] The Effort helped to develop much-needed opportunities for interaction between the two communities.

> I really enjoy working with the teachers. I enjoyed meeting the people who are teaching our children. Sort of a humanistic aspect I enjoyed the most. (Research scientist, Phase II)

> It's useful having time to spend with people who are doing astronomy and space science. That's an important first step in making any changes. People who I can respect professionally; I can continue to talk to them and seek them out in other places. (High school teacher, Phase II)

> My participation in the Ecosystem has helped in keeping my eyes open to the wider world. If I hadn't been going to the [Education] Council meetings, I don't think I'd be as aware of what's going on. (Mission scientist, Phase II)

By working together, scientists and educators became acquainted with each other's strengths, challenges, and motivations. This allowed scientists to more effectively transform their own research into effective E/PO resources. The interactions fostered by the NASA SS E/PO Effort supported the development of the cultural competency necessary for successful collaboration.

> First, you've got to get the scientists and the teachers in a room together and then you've got to get them to agree that one is not dumber than the other. (High school teacher, Phase II)

> Teachers work closely with a partner at NASA. So closely that they become part of the research group. The myth that teachers couldn't do it has been dispelled. They really learn the excitement of science firsthand and internalize it. (Mission scientist, Phase II)

> It's getting the two communities to understand their respective languages. They're coming from different worlds, and getting them to understand each other and each other's needs is a challenge. (E/PO lead, Phase II)

[23] *The Space Science Enterprise Strategic Plan*, 2000 (p. 23).

The NASA SS E/PO Effort has made steady progress toward creating partnerships between scientists and educators by orchestrating and supporting a variety of situations in which members of the two communities come together to share knowledge and work toward common goals, such as resource development meetings, review sessions, and long-term mentoring programs.

> We're mobilizing the scientific workforce for education. It's a tangible culture change. It's a unique contribution. It's not just the educators that need to teach science; it's not just the scientists that need to teach science. It's a partnership. We've been able to bring these people together—kicking and screaming sometimes, but it's working. (SN member, Phase III)

> Why would an educator trust me to teach him or her to teach a subject? I've learned to approach things so I'm respected, rather than scoffed at. A lot of scientists in the classroom are disasters. I understand more now about what leeway teachers have, schools have. I understand standards. I didn't know any of them that well. (SN member, final phase)

Much of the research on group dynamics suggests that the best way to forge relationships is to work toward a common goal.[24] Many of the partnerships within the NASA SS E/PO Effort were structured in a way that allowed participants to achieve more as part of a group than they would be able to achieve individually.

> It has to be mutually beneficial. You have to find that. You have to decide—Is there something I can do that will benefit them and is there something they can do to benefit me? Are we stronger together than alone?
> (Education administrator, Phase IV)

> There has to be a reason to work together. You can't just say, "Person from A and Person from B—work together." There has to be something to work on. That's when you really enrich each other's efforts. (SN member, final phase)

In 2002, the NASA SS E/PO Effort sponsored a conference that was dedicated to creating effective space science and education partnerships. Convened by the NASA SS E/PO Support Network, it comprised a three-day discussion about how to create effective space science and education partnerships to further the goals of the NASA SS E/PO Effort. Participants included scientists and other personnel from NASA SS and across NASA; representatives from a number of formal and informal education organizations; members of a range of minority professional organizations; and education and research faculty from a range of colleges and universities across the country. The conference fostered extensive dialogue about the range of interests, resources, issues, and conditions for each

[24] See, for example, Sherif, M. (1966) *In common predicament: Social psychology of intergroup conflict and cooperation*. Boston: Houghton-Mifflin, and Gully, S.M., Devine, D.J, & Whitney, D.J. (1995). A meta-analysis of cohesion and performance: Effects of level of analysis and task interdependence. *Small Group Research, 26, 497-520.*

population that create both opportunities and challenges to partnerships and collaborations for all participating communities.

Several members of the SN have expressed concern that the partnerships fostered by the conference, and by the work of the E/PO Effort over the past decade, would end when funding for the SN ended.

> The degree to which people can take advantage of the personal networks they've made will depend on the level of support. People may WANT to talk to each other, but need a reason to do it. The Education Forums provide a reason to do it. We don't know where SMD is headed with this to say what's going to happen. (SN member, final phase)

> I think that in ten years, there may be good communication and having a system of supporting small planetaria that builds on what we did, but maybe we'll be forgotten. That's good brokering. But I don't know if that would happen with the teachers because they're still dependent on us. (SN member, final phase)

COMMUNICATION

The NASA SS E/PO Effort implemented a variety of strategies to increase communication, both among its own members, and between its members and the various stakeholders in space science E/PO, including NASA's Office of Education, mission science and E/PO staff, and end users. The strategies included:

- Regular Education Council meetings where SN members, NASA administrators, and mission staff could meet face-to-face to discuss the most effective ways to develop and disseminate resources
- SN working groups, which promoted interaction among diverse SN components; several of the working groups were specifically dedicated to improving communication with stakeholder groups such as scientists, underserved populations, and community groups
- Regular newsletters and annual reports, as well as up-to-date content on websites, which provided information about SN and other NASA SS E/PO activities to interested parties
- The Space Science Education Resource Directory (SSERD), an online directory of NASA SS E/PO resources, described more fully on page 49, which provided end users with an easy way to identify, assess, and access resources that are appropriate for their needs

WITHIN THE SN

At the onset of SN, there was not a mechanism for an exchange of information relating to specific Forum and B/F events. B/Fs mentioned the need to access information about the missions from Forums, while Forums articulated the need for information about events from the B/Fs.

> What Brokers need are stories. Some of it gets provided in web pages or various means, but it would be nice to have consistency. (SN member, Phase I)

> We [Forums] are not getting information from Brokers about what is going on. As for missions, they were saying that putting things on web pages was not enough. We all needed a heads-up for more timely information. (SN member, Phase II)

The NASA SS E/PO Effort placed a premium on communication among its members. The Education Council met two or three times annually, providing opportunities to share successes and challenges, contribute to the development of the Effort, meet in working groups, and interact in unstructured ways.

> We have all grown in education because of the education conferences in Chicago, the joint conferences at ASP, and we've learned from all of those talks. We've all grown. (SN member, Final phase)

> The Ed. Council meetings and working groups were a good structure to share in the system, individual work of the support units. Working on projects together, reporting to each other what we were doing—information sharing . . . you have to have that in order to have a coherent system. (SN member, final phase)

The members of the SN reported that their communication and interaction with each other had a strong positive effect on the work that they do. Members said that they benefited from each other's expertise, formed alliances to create new resources, shared contacts and networks, and learned from each other's successes and failures.

> Well I think this Ed. Council group is a bunch of brilliant, knowledgeable people with different expertise: scientists, educators, programmers, engineers, and psychologists. The group that got attracted to this approach believes in innovation and trying new things. We learned from each other: we learned about pedagogy, how to best teach science, best practices, and how to develop curriculum. (SN member, final phase)

In addition, the NASA SS E/PO was proactive in communicating with other parts of NASA, especially since the reorganization, which emphasized the need for the various educational programs within NASA to coordinate their efforts.

> There's more communication among the education programs that set policy jointly among all the different parts of NASA. I don't know if that's caused by the Ecosystem, but I'm sure it played a part (SN member, final phase)

WITH SCIENTISTS

The approach that the SN took to developing E/PO did not necessarily align with the way that missions had been creating resources. Prior to the development of the SN, E/PO materials were often created to reflect specific missions, rather than scientific content. While that served the publicity needs of the mission, it did not necessarily serve the educational needs of end users.

> Education wants the science, the questions. They're not interested in the missions. The missions are means to an end. Of course, the mission scientists want to focus on the mission. (SN member, Phase II)

> The Forum is not mission-driven, but science-driven. Our mission is to do things that missions can't do. We put emphasis on integrating science from several missions. (SN member, Phase II)

When the SN was developed, some scientists expressed concern about ceding control of the E/PO related to their missions. Several scientists commented that they had been doing E/PO before and did not want to give up control of the content, nor the funds related to E/PO. The SN developed communication tools to build bridges between scientists and educators, and worked to create opportunities for scientists to work in education.

> [We need to] make sure we have healthy relationships with scientists in missions; we want to facilitate activities, not regulate them . . . to promote, not stifle. We don't want to be policemen or auditors. We have to avoid appearing like a government bureaucracy. (SN member, Phase II)

To help scientists understand the connection between themselves and the other system components, Forums and B/Fs created a range of products, beginning with the on-line *Explanatory Guide*, which "provides answers to questions frequently asked by members of the space science community who are preparing an E/PO segment to an NASA SS proposal."[25] The SN was aware of the limited free time that scientists have for education (discussed in more detail on page 37), and worked to maximize the effects of their participation.

> We are going to have to continue to work with the E/PO leads on missions and have them continue to use us as a resource, as a benefit rather than a burden. (SN member, Phase I)

Because Forums are housed at individual locations, they face a challenge in communicating with space science mission projects at other locations. Two of the larger facilities associated with particular Forums (the Goddard Space Flight Center and the Jet Propulsion Lab) housed missions that are related to other Forums' themes. Missions housed at or near their educational Forum reported better communication with Forum staff. Missions located far from their Forum often found communication difficult, and some reported feeling "neglected" by Forum staff.

B/Fs required access to information about the space science missions in order to fulfill their roles, both in terms of collaborating with scientists themselves and in terms of finding partners for scientists. This made their job of communication with space scientists and educators in their regions especially important.

[25] *OSS Explanatory Guide for Education Public Outreach Evaluation Criteria.* 1999, on-line document.

> If we are talking about impacting teachers, you need to do that at the grassroots level. It's an important role that Brokers can play. We need to work together [B/Fs and Forums]. We are the conduit [for] getting information to teachers . . . We still need to know about the missions in order to link scientists to our communities. (SN member, Phase II)

B/Fs labored intensively to establish their identities as a vital part of the Support Network and define their roles. Over time, their interactions with scientists became more frequent, and the Brokers became more valued for their contribution.

> I think there's always an element that felt like "What is this?" Aren't there the ERCs and AESPs in place? The other side, a lot of scientists and educators that got used to working with us and enjoyed us. We got used to working with you as a Broker, we enjoyed it, and now you are going away. (SN member, final phase)

WITH HQ AND THE REST OF NASA

As the SN developed and defined how it fit in with NASA's overall educational goals, its members made an effort to reach out to the greater NASA community, especially those involved in education. These attempts started early in the E/PO Effort's development.

> We clearly have a lot of work to do in terms of integrating all of this. We don't want to be a counter program. That clearly would be unproductive. We need to extend what we're doing with [NASA Education] staff. (SN member, Phase I)

Over time, the NASA SS E/PO Effort built ties to the rest of NASA and the larger space science E/PO community. The SN hosted several E/PO conferences which provided opportunities for members of the E/PO community to meet and network with each other, and which strengthened ties between the NASA SS E/PO Effort and the larger space science educational community.

> Recently we've created conferences to serve the E/PO community. We've had two of them, and a third at Adler. The conference has become a professional forum for E/PO developers. I've become energized through those conferences, finding partners with and beyond NASA. NASA gave them support, and now we have a professional venue where we can share ideas and provide PD experiences for each other. (SN member, final phase)

Before the onset of the SN, the profusion of materials available made it difficult for mission staff to find resources that would help them create good materials. There was not a common library of knowledge, nor was it easy for E/PO staff to find out what resources already existed.

> I get calls from the mission E/PO officers, asking for help in identifying the good material. (SN member, Phase I)

Nor was there a standard way for E/PO staff to describe and document their work. This made comparison between different resources difficult, and contributed to the challenge of identifying gaps in the universe of resources.

> They are looking for guidance about how to present their mission's E/PO efforts. We have not figured out a way to create a template to help E/PO officers of missions make available their mission stories in a consistent and usable way.
> (SN member, Phase I)

Over time, the NASA SS E/PO Effort developed systems to increase communication and coherence, both within the SN and with the rest of NASA.

> For the first time in NASA's history, there was a comprehensive picture of what they were doing and various education [programs] existed [together] in education. Space Science and Earth Science reached out.
> (SN member, final phase)

> There is a correlation between maturity of relationship within the Ecosystem and the ability to achieve more effective partnerships within NASA.
> (SN member, final phase)

WITH AUDIENCES

Traditionally, mission educational materials were created and distributed on a one-time basis from mission E/PO funds. The materials, including images, videotapes, and printed materials, were distributed via various venues, including NASA Education Resource Centers (ERCs) and national or regional conferences. ERCs sometimes faced challenges restocking popular items, while conferences provided materials only to those educators who were able to attend. This led to haphazard distribution, with materials going to those who were present, rather than those who had the most use for them.

> A lot of my frustration has been getting appropriate materials. It used to be easier, but within the past five years, it has been very difficult. If you get to go to NSTA conventions, though, NASA has big booths and you can get all sorts of stuff, but at ERCs, the stuff isn't there. (High school teacher, Phase II)

> It happens by chance. For example, a really great pamphlet is developed. It's really needed. That pamphlet is produced in 5,000 copies, distributed at a national meeting. And if a teacher is there, they get the resource; if they aren't, they don't. (Science education developer, Phase II)

The situation was frustrating for end users. There was often no provision for further re-supply since the materials creation budget ended when the mission ended. Useful material would become known and the demand for it would rise. Just as teachers or curriculum writers adapted it for use in a classroom, the supply would run out.

> Because we are a known NASA repository, [our site] frequently receives copies of printed materials that result from missions or projects, quantities that might vary from thirty to one hundred. When those materials are gone, there is often no way to re-supply them. This leads to great frustration. During the distribution, they find some of the materials are extremely useful to teachers. The word gets around, the demand rises, and then the supply ends. (ERC personnel, Phase I)

One strategy used to address this issue was the development and dissemination of electronic resources: materials that could be distributed online or on CD-ROMs.

> Product dissemination is an issue. It's being addressed in a lot of ways. Mostly looking at hard copies. We need to look at other ways: electronic versions. It's not the ideal solution, but when you have a limited supply of money, it may be the only way. (SN member, Phase I)

The Web as a medium, particularly the NASA web pages, presented some challenges to teachers:

- Many teachers have limited access to or familiarity with new technology. Computers in schools are rarely state-of-the-art instruments. Many schools are not wired for Internet access. Those that are, often have older equipment and slower modem speeds. In some cases, Internet access is denied to teachers and students out of a fear that inappropriate materials will appear in schools.
- Users reported being frustrated with their ability to move around the sites and find relevant information. Even if they could access the information electronically, they sometimes had difficulty wading through the content. Several teachers in on-line discussions with NASA SS personnel commented on the difficulty of finding materials on the website to meet specific needs. They reported that much of the material available was more appropriate for those already familiar with space science.

Early versions of the NASA portal website were difficult to navigate and use. Users reported that it was difficult to find specific information or images. Data indicate that linkages between SMD pages (http://science.nasa.gov) and the main NASA pages (http://www.nasa.gov) remain counterintuitive and the search functions, difficult to use.

> We tried to get a direct link. It makes me crazy on NASA web pages. I just want to find an activity about the moon and can't find it. It makes me crazy. (SN member, Phase II)

> I've looked at the OSS websites. They aren't that useful because there is so much there and it's not that well organized. I usually just use a search engine to find what I need. (E/PO staff member, Phase II)

> It's a big website with lots of stuff. Sometimes I get lost in there for hours, going from place to place, and then I don't remember why I went there. (Teacher, Phase III)

Frequent changes in the structure of NASA's web hierarchy have posed additional challenges.

> I think on the web pages, things may be harder because they changed the links, and it's hard to find things if your bookmarks don't work any more. I lost the bookmark for the SN and had the hardest time finding it. I don't know if it's because NASA has 50 gazillion pages. I think people are frustrated trying to navigate within the NASA portal. I think it's worse now. It became more complex after they did it. (SN member, final phase)

This issue of end users' ability to find resources was addressed in part by the development of the Space Science Education Resource Directory (SSERD, http://teachspacescience.stsci.edu/cgi-bin/ssrtop.plex), the result of collaboration across a number of institutions within the SN. The NASA SS E/PO Effort considers the SSERD to be one of its major achievements, and asserts that the directory would not have been developed without the SN.

Various versions of the SSERD were piloted at national conferences, and changes were made based on teacher comments and recommendations. The SSERD was made available to the public in October 2000. Over 500 space science lesson plans, educator guides, student activities, space science images, and other materials contributed by more than 30 NASA SS-sponsored programs are now registered in the SSERD's database. More than 400 of these resources are electronic PDF files or websites that are also publicly accessible to the education community through the SSERD's user interface. All resources available through the SSERD have been vetted for scientific accuracy. In addition, a subset of SSERD products are "panel approved," meaning that a panel of professional educators and scientists have determined that both the educational and scientific content is outstanding.

The resource directory has generated a great deal of interest among educators, and members of the NASA SS E/PO Effort reported that they have had positive feedback about the directory. SSERD usage has increased steadily since its inception, doubling between 2003 and 2007. Current usage averages 22,000 sessions per month. Users include visitors from K–12 Internet Service Providers (schools, school districts, resource centers) in all 50 states, as well as higher education institutions, libraries, museums, and science centers.

The SN further addressed the challenges of dissemination by reaching out directly to audience members and leveraging existing networks to increase awareness of the E/PO Effort and its resources. The SN established contact with pre-existing networks, and fostered the creation of new networks of educators by hosting them at NASA facilities where they could learn about space science by working with active researchers.

> And they are aware of NASA involvement in education, [more] than people at HQ—in that sense . . . we've had people say to us, what is NASA going to do next year? What more things do you have? A lot of people who didn't know about NASA resources know about them now. (SN member, final phase)

Data indicate that the Brokers, with their regional focus, were able to reach large, diverse audiences that had been underserved by NASA's traditional methods of dissemination.

> Because we're focusing on a region, we can reach people who wouldn't have access. NASA is building relationships with NSTA, which is great. But many teachers in Kansas don't go to NSTA conferences. Many aren't even members, but we can reach them. (SN member, final phase)

The SN was in a position to initiate personal, one-to-one communication with end users, and this proved to be an effective strategy with audiences who had limited knowledge of NASA's educational resources. The SN supported a cadre of educators who developed expertise in space science and science pedagogy. These educators were able to act as leaders in their communities, sharing their new knowledge with colleagues.

> They have a much better awareness of what NASA can and can't do than they would have if they hadn't interacted with us. I think there are end users who think of NASA as this big faceless company, and I think what's been interesting and valuable to some of the end users is understanding and becoming acquainted with some of the faces behind NASA. That there are real people behind NASA and they're trying to help. (SN member, final phase)

Communication with users continues to be a challenge. End users are not currently aware of the dissolution of the SN. B/Fs report that they are still getting requests for support of workshops and other resources that will require input after their NASA SS E/PO funding expires. Visitors to the B/F websites are being redirected to contact SMD for assistance.

UNDERSTANDING AUDIENCE CONSTRAINTS

NASA personnel work in an environment that is very different from that of their audiences. Educators face a variety of challenges that may not be apparent to scientists. From its inception, the SN was pro-active in learning about audience needs.

> NASA has done what no other agency can do. The networking thing, I can't speak highly enough about that. It's the single most important thing. It made it possible to interact with all these end users. The Ecosystem has vastly increased our access to end users. (SN member, final phase)

> I would [attribute the success of many NASA E/PO resources] to NASA's much greater willingness to partner with end users and learn about the needs and the culture. (SN member, final phase)

The SN disseminated its knowledge of user needs to the rest of the NASA E/PO community.

> One of the key things they helped us with was understanding of user needs, especially when we are developing a new community. For example, [one institution] became very involved with the Girl Scouts, and they shared their knowledge with the rest of us. It became a mentoring process.
> (SN member, final phase)

FORMAL EDUCATION

Given the financial constraints faced by most teachers, even small amounts of money can make a large difference. While some districts provide support to teachers who seek out additional resources to engage and stimulate their students, many K–12 teachers report

spending their own personal money to provide materials and resources they consider vital to their teaching.

> As a teacher, the school gives me $100 for the year, including pencils and paper. That's a communication problem between teachers and NASA. Someone at [a NASA center] said, "Boy, you teachers just want everything for free." I don't think they realize that everything we buy comes out of our own pockets. (Elementary school teacher, Phase II)

One serious challenge faced by formal educators is the need to meet national and local standards and to prepare students for standardized tests. The materials that NASA had prepared prior to the development of the NASA SS E/PO Effort were not always designed to meet this challenge, and teachers found it difficult to fit non-standards-aligned materials into their curriculum.

> We have standards we need to meet and we need something that shows the connections between the standards and the topics. It's hard and inefficient to assemble a curriculum from pieces. (Teacher, Phase I)

> There are time constraints and curricular constraints imposed by the standards. (Middle school teacher, Phase II)

> Assessment drives your practice in a way; it affects what you want your kids to know and be able to do. (Elementary school teacher, Phase II)

Developing classroom lessons that work well posed a particular challenge. Such lessons need to create student excitement, be manageable in existing classrooms, raise science questions that make sense to students, and have dimensions that can be investigated and explored by them. Teachers reported that they need resources that align easily with existing curricula, rather than stand-alone materials that are difficult to integrate into already full schedules.

> Teachers often say they don't need any more curriculum units. They are inundated with them already. They need material that will work well in the classroom, material that engages the students, gets them excited, and provides ways to do investigations in the classroom. Teachers feel that they can incorporate good material and make it fit into their classrooms. And every teacher feels that they need to modify and tailor lessons to fit their own classrooms and situations and students. (SN member, Phase I)

INFORMAL EDUCATION

Museums and science centers vary greatly in terms of staff and materials, and computer access to the Internet. This last issue was particularly important for exhibits that utilize real-time data from the Web. While several NASA SS-related exhibits successfully incorporated the Web (for example, a solar eclipse-based event at San Francisco's Exploratorium that included remote access coverage of the eclipse happening on the other side of the world), utilizing the Web often posed problems for smaller institutions.

> You can't assume that a museum will have Internet connection on the museum floor. So, you can't include real-time information as an integral part of the exhibit. If it's a fixed exhibit, you can set it up at the site so you have the live feed. If it's a traveling exhibit and net access is necessary, you limit the number of potential sites. There are more science centers and planetariums all the time. It seems like every little town has a science center, but they can't handle a 5000 square foot exhibit. It's analogous to the less technologically advanced schools who can't handle the net-accessible stuff. (SN member, Phase I)

Many informal exhibits utilized exciting new technology. Exhibit components such as remote-controlled spacecraft, interactive computer displays, and kiosks that provide the up-to-date astronomical information are popular with museum staff and visitors alike. However, some smaller institutions reported difficulties in keeping these materials functioning, and requested more support in maintaining complex electronic components.

> The [exhibit component] was up and down for a month. We never really found out what happened. Our technician was working with the designers. We were replacing boards and other stuff. That was a problem, because it was the best piece in the thing, and when it worked, it was great; when it didn't, it was disappointing. (Museum staff, Phase III)

UNDERSERVED POPULATIONS

Reaching out to diverse students was identified as integral to the development of the pipeline for the NASA 21st century workforce. Non-whites, females, and persons with disabilities are underrepresented in research fields, especially the hard sciences. This problem is especially acute in space science, which is very much the domain of the white male.

> At HQ, there are *no* African Americans in space science. I don't think there are any Hispanics. There are probably four or five Asian Americans. At field centers, the situation is probably about the same. There are probably one or two Hispanics. I can't think of any African Americans who wear the NASA badge. (SN member, Phase II)

> So far, I've never been able to find any way into NASA. The [program] scientists I have talked to are very interested. They may like your project, but they are so overwhelmed with their own responsibilities—unless you can offer them something they do not have, there is no point for them—they get little for it. (Minority scientist, Phase IV)

Because there are so few minority scientists, their voices are not heard, and the needs of U/U groups are not understood. Consequently, the cultural divide between the space science community and the people it hopes to serve through the E/PO Effort is especially large.

The NASA SS E/PO Effort recognized the importance of creating an environment that would be welcoming to a more diverse population. They hosted conferences for minority

professional organizations, recruited members of underserved populations to sit on E/PO development teams and review boards, and they created a working group to bolster the cultural competence of the largely white Support Network.

Data indicate that the pool of minority scientists will not increase unless more underserved students are inspired to pursue careers in space science. Minority students are underrepresented in hard science majors, just as minority adults are underrepresented in scientific careers. Data suggest that interest in science begins, or ends, at a young age. Thus, to support the 21st century workforce, educational materials need to foster the curiosity of younger students.

> I specifically think that reaching minorities is critical to the long-term health of the field. As a college professor, we may want more faculty members of color but you cannot suck on a dry bottle. You have to get to the pipeline further down. To me, I think that the pipeline is slowing, and I think that it is critical to infuse energy at all levels of the process. (Scientist, Phase IV)

Educators in poor rural or inner-city communities typically have limited access to computers and the Internet. The high-tech, on-line materials that NASA creates do not necessarily meet the needs of those without access to high-speed Internet connections. This is particularly problematic in U/U communities where face-to-face interactions are seen as integral to building trust.

> The Internet doesn't work in my community. You need that personal touch. Science is viewed as an aberration. It's a fearful entity in the black community. You need someone to generate the motivational impulse.
>
> (Minority scientist, Phase II)

Underserved students may have had limited access to both technology and courses that adequately prepare them for a college education in the hard sciences. Data indicate that underserved freshmen may be ill prepared in mathematics—even to the extent of being unable to work with fractions. This poses significant challenges to both students and educators.

The family and culture of some underserved students may also pose challenges. For example, earlier PERG evaluations have included data and analysis suggesting that traditional science courses may oppose Native American ideology, that Hispanic culture may discourage students (especially female students) from engaging in higher education, and that African American students are less likely to have access to computers or the Internet at home.

The NASA SS E/PO Effort placed emphasis on increasing the participation of minorities in space science, with the goal of diversifying the space science workforce. It forged relationships with minority institutions and minority professional organizations, and targeted urban schoolteachers working with multi-ethnic populations, providing them with resources and PD opportunities.

> Of all the organizations I've dealt with, NASA is the most supportive and proactive about finding out what we're all about. They'll send people to our meeting; they'll listen and will try to come up with ideas and things to do. Much more proactive than NSF or DOE.
> (Minority science organization member, Phase III)

> NASA is clearly the leader amongst federal agencies in having a real, true, demonstrated interest in trying to expand the scope of schools that are involved with NASA programs. (Professor of color, Phase III)

The NASA SS E/PO was conscious of the need to reach underserved students and provide role models for them. They reached out to scientists and educators from underserved communities to learn about user needs and to provide role models for students who may not see themselves as potential scientists or engineers.

> In urban areas, students have limited scope, short horizons on what they can do in life. [They do] not have a sense of what work is possible outside their immediate neighborhoods, no role models . . . things such as science and technology come across totally as fiction. SUNBEAMS and the association with NASA helps make concrete for them that there are possibilities beyond their immediate communities. (Teacher, Phase IV)

> Everyone knows that they are working with the future demographics of America and that awareness carries through in the commitment I see in the participating faculty. They all know they are trying to do something good.
> (Minority scientist, Phase IV)

> I am extremely impressed with what [the management of the NASA SS E/PO Effort] is doing, especially in relation to minorities. I think it began when [the administrative head of the OSS E/PO Effort] began visiting minority institutions to see what's needed to make it work. (Minority scientist, Phase II)

In May 2001, members of nine minority professional societies met with members of the NASA SS E/PO Effort to address the goal of creating new research and education projects that will involve minority scientists and students.

> The general idea is that a couple of people from each of these organizations and a couple of people from each of the SN modules will meet. Hopefully, they will develop near-term projects that can be done in collaboration and lay out how such partnerships can be facilitated in the future. We need a mechanism for doing this in the future. (SN member, Phase II)

The OSS E/PO Effort recognized the importance of incorporating diverse voices *from the beginning* of the development. The strategy is to allow conversation among diverse communities during development, to ensure that their needs will be met.

> It doesn't work well if we wait until the project is completely defined to invite in new voices; they need to be involved from the beginning. (SN member, Phase II)

> The best way to create projects that are appealing to minority students is to get minority scientists involved in development. I think [a minority scientist's]

> instincts about what will appeal to minority kids will be more accurate than lots of federally funded studies. (SN member, Phase II)

Data suggest that partnerships with minority scientists, once developed, can help bring space science into those schools and communities serving U/U populations, and by extension, bring a more diverse population into the space science community. If scientists from diverse communities are present in the planning process, they can help create resources that are appropriate for other members of their community.

> It's important to start by listening carefully to advice of the communities we want to work with. It seems that it is important to have members of those communities from day one for the planning. The question is: How do we set up a way to make the right contacts that can lead to that kind of involvement?
> (SN member, Phase II)

> [It's] the most effective [way to reach] minority groups, because it is a sustained and long duration program. By linking with them, we are part of something that's already in the infrastructure of participating groups. (SN member, final phase)

CLOSING REMARKS

The NASA SS E/PO Effort made remarkable progress during its relatively short tenure. The data indicate that there has been a noticeable change in the way that individuals both within and without NASA view space science education, and that the activities of the Effort contributed to these changes.

Within the scientific community, E/PO work is more highly valued. There have been a number of awards given for E/PO work, a new journal dedicated to astronomy education, and an increased awareness of both user needs and the skills and content needed to meet these needs. Many of those who have participated in the NASA SS E/PO Effort say their increased understanding of user needs has been incorporated into the design of E/PO resources.

Among educators and learners, there is an increased awareness of NASA as a source of inspiring, engaging, and scientifically accurate educational materials. Increased scientist involvement in education has contributed to educators' and learners' understanding of the roles scientists and engineers play.

The Effort expanded its reach both in terms of the number of individuals within NASA who supported and contributed to education and public outreach and in terms of the range and diversity of audiences served by NASA space science resources. Many of those who have participated in the Effort, whether as scientists, resource developers, or end users,

said that they have been affected by their involvement with NASA E/PO and that the experience has left an impact upon them that will persist past the term of the current Effort.

APPENDICES

Appendix A: NASA OSS E/PO SN Interview Protocol

Appendix B: Glossary of Acronyms and Terms

APPENDIX A
NASA OSS E/PO SN INTERVIEW PROTOCOL

PERG is looking back at the past decade or so of NASA SS education, to document what happened as a result of the strategy, and what, if any, effect the strategy has had on the space science and education communities. By strategy, we mean the E/PO strategy documented in *Partners in Education*, the 1995 document detailing a strategy for integrating education and public outreach into NASA's Space Science programs. This strategy—which included the development of the Support Network, the inclusion of scientists in SS E/PO, and mandating E/PO components for all missions—was originally referred to as the "Ecosystem," then as the OSS E/PO program. It is currently part of the NASA SS E/PO program. For the sake of clarity, in this interview, we will refer to this strategy by its original name: The Ecosystem. We will also talk about NASA as a whole and the agency's approach to education. When we refer to NASA E/PO, we mean all education activity that originates in NASA, including the Ecosystem, any other educational activity in SMD, the work of NASA's Office of Education (called Code FE at the time the Ecosystem was developed, then Code N, now the Office of Education).

Your insights are greatly appreciated.

Background

When did you first become involved with the Ecosystem? Had you been involved in NASA E/PO prior to this?

How did you get involved?

PROBE For "why?" Reasons got involved, what you get out of it

General Reflection on the System

How, if at all, has the way NASA approaches education changed?

What do you think caused, or contributed to, these changes?

What, if any, changes to NASA' approach to education do you believe are attributable to the Ecosystem?
(E.g. building partnerships between scientists and educators, developing a support network to facilitate the development and dissemination of SS education resources, and mandating education as part of all mission budgets)

What changes, if at any, have you seen in the awareness and understanding of space science education within NASA?
(E.g. attitudes at HQ, involvement of other NASA enterprises)

What evidence do you see of these changes?

What do you think caused or contributed to these changes?
PROBE for impact of the Ecosystem?

How, if at all, has NASA as a whole reacted to the Ecosystem?
PROBE: Support, interest, cultural alignment
PROBE: Reaction from different groups within NASA (HQ, scientists, other enterprises)

How, if at all, has NASA's reaction to the Ecosystem changed over time? (Same probes as above)
What evidence do you see of these changes?

Personal Growth

What role or roles have you played in the Ecosystem? What, if any, roles have you had in NASA Education beyond the Ecosystem?
Have your roles changed over time?

How has the Ecosystem supported your understanding of E/PO?
PROBE for PD, workshops, conferences, and partnerships

How has the Ecosystem supported your growth as an E/PO developer?
PROBE for PD, workshops, conferences, and partnerships

How, if at all, has your involvement in the Ecosystem affected the way you think about SS E/PO and the activities you undertake to support it?
(E.g. understanding of schools, museums, educator constraints; learning about pedagogy; getting input from various populations such as scientists, education specialists, and end users; new processes for assessing resources; strategies for developing, adapting, and leveraging resources)

How do you anticipate using what you've learned during your involvement with the Ecosystem?
(E.g., develop new or different resources, change the way you interact with end users, share your knowledge with others)

End Users and Resources

What types of end users, if any, have you interacted with?
(By end users we mean people who use and learn from NASA SS resources, such as teachers, students, museum staff, Girl Scouts, amateur astronomers, members of the public who attend SS events, etc.)

How, if at all, has your involvement in the Ecosystem affected the way you interact with end users?

How have end users responded to the SS E/PO resources you have shared with them or directed them to?

How, if at all, has end user response to SS E/PO resources changed over time?

What evidence do you have of these changes? (Anecdotes, observations)

What do you think caused or contributed to these changes?

How, if at all, do you think the Ecosystem has affected end users' ability to find, access, and use NASA SS E/PO resources? What evidence do you have for this?

How, if at all, has your involvement in the Ecosystem affected the types of E/PO resources you develop or support?

What, if any, resources were developed or enhanced as a result of the Ecosystem?

Are there specific resources that you consider to be "successes" for the system? If so, what are they?

Why do you consider them successful?

Do you have contact information for the creators or users of these resources?

Closing Questions

What, if any, additional issues do you think are important to the evaluation?

Are there specific people you think we should talk to, or resources you think we should look at, to better understand the impact of the system?

Do you have any other comments you'd like to share with us?

APPENDIX B
GLOSSARY OF ACRONYMS AND TERMS

AA: Assistant Administrator, the head of an Enterprise or Office in NASA (ranking below Administrator)
AAA: Associate Assistant Administrator, the head of a Division within an Enterprise or Office in NASA (ranking below Assistant Administrator)
AO: Announcement of Opportunity, a solicitation of proposals for mission funding
B/F: Broker/Facilitator, part of the Support Network (SN), charged with linking educators, scientists, and others
CAN: Cooperative Agreement Notice
Education Council: The administrative core of the NASA SS E/PO Effort, it included the SN, OSS/SMD E/PO administration, and staff from both OSS/SMD E/PO and NASA's Office of Education
Education Forum: part of the Support Network (SN), each was aligned with one of the former space science themes (Sun-Earth Connection, Solar System Exploration, Structure and Evolution of the Universe, and Origins of the Universe) and charged with creating coherence among the missions associated with that theme
ENWS: Exceptional Needs Workshop, a workshop to support making SS resources accessible to those with disabilities
E/PO: Education and Public Outreach
ERC: Education Resource Center, hubs for the distribution of NASA educational materials
ESMD: Exploration Systems Mission Directorate, more information at http://exploration.nasa.gov/
Forum: See Education Forum
GLPA: Great Lakes Planetarium Association, a network of small museums and science centers in the Great Lakes region
GSUSA: Girl Scouts of the United States of America
HBCU: Historically Black College or University
HIS: Hispanic Speaking Institution
MSIP: Mars Student Imaging Project
MUI: Minority University Initiative
MUCERPI: Minority University and College Education and Research Partnership Initiative in Space Science
MURED: Minority University Research and Education Division, now part of the Office of Education
NASA: National Aeronautics and Space Administration
NEEIS: NASA Education Evaluation and Information System, an online system for tracking NASA Education activity
NRA: NASA Research Announcement, a solicitation of proposals for Supporting Research and Technology funding
NSF: National Science Foundation, a funding source for scientific research and E/PO
NSTA: National Science Teachers Association

PD: Professional Development
PERG: Program Evaluation and Research Group, the external evaluator for the NASA SS E/PO Effort
OSS: Office of Space Science, formerly one of NASA's enterprises, now part of the Science Mission Directorate (SMD)
PD: Professional Development
ROSIE: Regional Opportunities for Scientists in Education, a table of E/PO opportunities for scientists
ROSS: Research Opportunities in Space Science, an NRA soliciting basic research in support of the space science missions
SMD: Science Mission Directorate, one of NASA's enterprises, comprising Earth and space science, more information at http://science.nasa.gov/
SN: Support Network, the network of Forums and Broker/Facilitators developed to support the SMD E/PO mission
SS: Space Science
SScAC: Space Science Advisory Committee, an oversight committee for the former OSS
SSERD: The Space Science Education Resource Directory, an online directory of NASA SS resources
STEM: Science, Technology, Engineering, and Mathematics
SUNBEAMS: Students United with NASA Becoming Enthusiastic about Math and Science, more information at http://hesperia.gsfc.nasa.gov/~gilbert/sunbeams/SB%20Prog%20Page.htm
U/U: Underserved/Underrepresented, used to describe communities or populations that have received less benefit from NASA SS materials than the mainstream population